# CHAPTER 4. RESULTS AND DISCUSSION

The methods developed and described in this study have been applied successfully by Van Staden (1992), whose methods were based on this study, and his results are, therefore, used to substantiate this work, where necessary.

Field work in the main study area is ongoing and 63 stands with a total of 270 sampling units have been sampled. Much of the work in this area has been developmental; for example the reconnaissance methods advocated were not applied comprehensively from the outset and several cover estimation techniques were used before the plant number scale (Westfall & Panagos 1988) was developed.

## 4.1 *PREPARATORY WORK*

Analysis of computerized rainfall data supplied by the Weather Bureau, on request, for 21 stations within the main study area, with records for periods longer than 20 years, gave the following regression, according to the formula y=ax+c:

$$y = 154\ (x) + 379$$

where y = mean annual rainfall; and

$$x = \frac{\text{altitude (m)}}{1\ 000} \times (\text{latitude (decimal degrees)} - 23{,}5)$$

A correlation coefficient of r=0,90 between the x and y values,

was obtained using the statistics utility in the PHYTOTAB-PC program package. A poor correlation between the variables was, however, obtained when stations outside the study area were included, where a rain shadow effect seems to occur. This implies that mean annual rainfall, for any stand within the main study area, can be estimated from the altitude and latitude of the stand. The technique illustrates the feasiblity of using regressions to predict rainfall on a stand basis, in studies where topography can influence rainfall.

### 4.1.1 Scale

The scale used in this study and that of Van Staden (1992) is 1:250 000 which is considered commensurate with the detail required by the Department of Agricultural Development for vegetation resource inventory at a regional level. Stand radius is, therefore, 250 m and minimum stand spacing is 500 m (section 3.1.5). The smallest area for a stratified unit, in which four stands with minimum stand spacing can be included, is approximately 314 ha. This in effect, relates to a stand and spacing radius of 500 m per stand or approximately 78,5 ha per stand. The minimum of four stands per stratified unit is based on the same argument as the minimum number of sampling units per stand (section 3.1.6) and relates to stratified unit variation sampled. The stratified unit is that area mapped for sampling the vegetation. The vegetation unit is the area classified as a relevè or group of relevès. Correspondence between the stratified unit and vegetation unit can

assist in verifying a classification.

The high degree of correspondence between stratification, classification and environment, achieved by Van Staden (1992), is attributed mainly to cognizance being taken of scale. Scale determines the minimum area of a vegetation unit or potential community which is taken to be a stand. Scale can also influence environmental correspondence with vegetation units. For example, at biome scale (1:10 000 000) the vegetation units, or biomes, correspond to seasonality and summer aridity (Rutherford & Westfall 1986). Within a biome, rainfall, geology and soils can vary considerably, such as rainfall in the Fynbos Biome, which varies from about 300 mm to over 2 400 mm per annum (Rutherford & Westfall 1986). These factors can be expected to differentiate vegetation units at scales larger than biome scale, hence the differentiating environmental factors for a vegetation unit can be regarded as being scale-related. If scale is not taken into account, especially in small-scale work, then mixed scales could result, thereby complicating environmental correspondence and syntheses of studies.

On the other hand, cognizance of scale does not appear to be as critical in large scale work. This can be attributed to sampling unit area either, being similar to stand area or, being of such an area that it can be representative of a stand, without the stand being defined in terms of scale.

Scale also relates to heterogeneity, where stands at large scales are likely to be relatively homogeneous, whereas, as scale de-

creases, heterogeneity is likely to increase. This is also likely to apply to the vegetation units of which the stands are a part, so that the heterogeneity of a vegetation unit is inversely proportional to scale. Thus, cognizance of scale can also aid the sampling of mosaics in vegetation, where scale determines whether the components of the mosaic should be sampled separately or jointly.

Scale can also affect sampling intensity, for example, at biome scale (1:10 000 000) sampling intensity in terms of stands per km² would be considerably less than at 1:50 000 scale. However, in order to adequately sample the increased vegetation variation at biome scale, stand radius at biome scale is considerably larger, being 10 km, than the 50 m required at at 1:50 000 scale. Thus, increasing stand area for decreasing scale compensates for increasing heterogeneity with decreasing scale.

### 4.1.2 Stand area

The stand area, for the main study area as defined in section 3.1.2, corresponds to a scale of 1: 250 000. The stand radius is, therefore, 250 m with stand area being approximately 20 ha.

Decisions required for stand definition are inversely proportional to scale. In other words the smaller the scale the more difficult it is to identify a stand of vegetation at the required scale. The direct association advocated in this study between scale and stand area is the means by which scale is taken into account during

sampling and is also easy to apply. The stand is integral to the Braun-Blanquet approach to vegetation sampling (Mueller-Dombois & Ellenberg 1974). Its relevance can be considerably increased for small scale work by the definition proposed in this study without invalidating large scale work.

It is interesting to note that the stand area of the Veld Types (Acocks 1975, 1988), according to scale, would have been about 7 $km^{-2}$. This is approximately the area covered by Acocks during sampling (J.C. Scheepers pers. comm.)

A practical application of the stand, as defined in this study, is the determination of the minimum area required for conserving and sustaining a particular vegetation unit. The minimum sustainable area for a vegetation unit is the stand at the largest scale at which the vegetation unit can be recognized. However, the periphery of such a conserved unit is likely to change with time, depending on practices adjacent to the border of the conserved unit. A buffer area would, therefore, be required. This buffer area can be equated with the ecotone or transitional area, between two communities, which is also related to scale. The minimum sustainable area (s) for a vegetation unit is, therefore, given by:

$$s=\pi 2r^2$$

where s=minimum sustainable area ($m^2$) and r is equal to the denominator, in metres, of the largest scale, as a representative fraction, at which the vegetation unit can be recognized.

### 4.1.3 Reconnaissance

Approximately 60 structural/floristic units were estimated present in the main study area at the relevant scale during reconnaissance (see section 3.1.3). The structural/floristic unit total was a deliberate over-estimate for adequate colour allocation in the stratification process (section 3.1.4). Species richness averaged 11 species per $m^2$ as determined by regressions of species counts in 4 $m^2$ quadrats, selected to represent the range in species richness variation. These results were obtained using the sample/stand dimension utility in the PHYTOTAB-PC program package and are required for determining minimum sampling unit dimensions (sub-plots) for stand sampling.

The minimum requirement of a reconnaissance of a study area is an estimate of the variation in vegetation expressed as the approximate number of vegetation units at the scale required. This is essential for both stratification and classification. The criterion of species richness to determine sampling unit dimensions, is only necessary where stands are subsampled. The particular aim of a study will determine whether other variables require preliminary assessment of variation. However, observations on vegetation/environment relations should be made for initial model construction (section 3.4.2.3). Voucher specimen collection of the common and dominant plant species, can also be made during reconnaissance, for initial plant identification key purposes, as these are the species most likely to be encountered during sampling.

### 4.1.4 Stratification

A total of 44 units were stratified in the study area at the relevant scale. The smallest stratified unit is such that four stands, each with buffer zones equal to the stand radius, could be included (section 4.1.1). The buffer zones provide for possible ecotones, at the relevant scale, should community borders fall between two stands and also ensure non-contiguity of stand placement. The area represented by the smallest stratified unit is, therefore, approximately 314 ha.

The successful use of LANDSAT MSS data to differentiate vegetation units corresponding to plant communities is shown in Van Staden (1992). The ground resolution of LANDSAT MSS data, of approximately 79 x 79 m, is such that individual plant differences are unlikely to affect spectral characteristics for small-scale work. The textural and contextual detail of plant communities at this scale are such, however, that a fairly wide range of structural and cover variation can be tolerated, locally, within a plant community. In this sense, structure refers to the horizontal zonation of the vegetation. Van Staden (1992) has shown a high correspondence between vegetation units, classified on the basis of floristics, and stratified units, determined by means of satellite imagery, despite variations in cover because of severe overgrazing. It is likely that utilization of a particular layer of vegetation, can be offset over time, by an increase in phytomass in a different layer so that the effect of grazing on aboveground phytomass, is reduced. Furthermore, Van Staden (1992)

has shown that the environmental gradients differentiating plant communities relate primarily to available moisture, in terms of effective soil depth. This implies that adjacent plant communities differ in the availability of moisture, which is probably the main factor limiting phytomass, in the study concerned. Although plant communities with similar structure can be floristically different, and *vice versa*, it is suggested that the combination of structure and cover, which is a function of phytomass, can differ in adjacent plant communities. This leads to the assumption that total aboveground phytomass is more likely to be responsible for differences in plant community spectral characteristics than either structure or cover alone, in the study concerned. Hypothesis i (section 1.3) is, therefore, not disproved.

It is often highly arbitrary to delimit vegetation units primarily according to an environmental factor, such as altitude, which mostly forms a continuum in its range. The decision as to what particular altitude constitutes a discontinuity in the vegetation must, therefore, take the vegetation into account. The methods used in this study for stratification of vegetation suggest improvements, for small scale work, to the usual method of aerial photograph interpretation where topography and vegetation are visually integrated. Rather than visually integrate topography and vegetation, the primary delimitation could be done according to pattern analysis of vegetation. Topographic features would then play a secondary role and scale could be taken into account.

This would entail, firstly, constructing a transparent overlay

TABLE 4.1. - PHYTOLOC output for random location of stands, showing random point numbers, x-y co-ordinates for overlay grid and corresponding latitude and longitude, in degrees (to the left of the decimal), minutes (first two decimal places) and seconds(third and fourth decimal places with decimal fraction following). Stand numbers are consecutive and are not necessarily those of the random points.

| COORD NO. | X-AXIS, | Y-AXIS |
|---|---|---|
| 1 | X-AX= 53 | Y-AX= 123 |
| Lat | 24.41390147 | Lon 28.00590064 |
| 2 | X-AX= 83 | Y-AX= 89 |
| Lat | 24.2313596 | Lon 28.1900061 |
| 3 | X-AX= 73 | Y-AX= 52 |
| Lat | 24.03106403 | Lon 28.13339644 |
| 4 | X-AX= 25 | Y-AX= 90 |
| Lat | 24.23461083 | Lon 27.44453031 |
| 5 | X-AX= 89 | Y-AX= 25 |
| Lat | 23.48328078 | Lon 28.2332387 |
| 6 | X-AX= 30 | Y-AX= 107 |
| Lat | 24.32588177 | Lon 27.47371387 |
| 7 | X-AX= 101 | Y-AX= 102 |
| Lat | 24.30162561 | Lon 28.29241894 |
| 8 | X-AX= 13 | Y-AX= 111 |
| Lat | 24.3508867 | Lon 27.37375639 |
| 9 | X-AX= 65 | Y-AX= 78 |
| Lat | 24.17159605 | Lon 28.08298468 |
| 10 | X-AX= 75 | Y-AX= 3 |
| Lat | 23.36375369 | Lon 28.15248322 |
| 11 | X-AX= 52 | Y-AX= 106 |
| Lat | 24.32263054 | Lon 28.0032904 |
| 12 | X-AX= 75 | Y-AX= 118 |
| Lat | 24.38564532 | Lon 28.13544628 |
| 13 | X-AX= 98 | Y-AX= 20 |
| Lat | 23.45502462 | Lon 28.2902484 |
| 14 | X-AX= 55 | Y-AX= 64 |
| Lat | 24.09407881 | Lon 28.02425018 |
| 15 | X-AX= 37 | Y-AX= 43 |
| Lat | 23.58180295 | Lon 27.52084009 |
| 16 | X-AX= 52 | Y-AX= 106 |
| Lat | 24.32263054 | Lon 28.0032904 |
| 17 | X-AX= 90 | Y-AX= 63 |
| Lat | 24.09082758 | Lon 28.23323076 |
| 18 | X-AX= 9 | Y-AX= 111 |
| Lat | 24.3508867 | Lon 27.3516775 |
| 19 | X-AX= 63 | Y-AX= 26 |
| Lat | 23.49053202 | Lon 28.07532632 |
| 20 | X-AX= 55 | Y-AX= 52 |
| Lat | 24.03106403 | Lon 28.02494252 |
| 21 | X-AX= 17 | Y-AX= 98 |
| Lat | 24.28062068 | Lon 27.40006091 |
| 22 | X-AX= 32 | Y-AX= 21 |
| Lat | 23.46227586 | Lon 27.49163862 |

with the dimensions of the smallest stratified unit, at the required scale, adjusted to that of the aerial photographs, as a guide. Then mount the aerial photographs on a wall to form a single image. Observation distance is that at which the smallest homogeneous pattern, represented by textural detail on the aerial photographs, is no smaller than that of the overlay guide, at the same distance. Confusing detail at larger scales than required is thus avoided. Finally, trace the borders of all homogeneous pattern units, greater than or equal to the area of the guide, and recognizable at the observation distance, onto the aerial photographs. Vegetation as represented by pattern, is thus the sole criterion of primary delimitation. Secondary delimitation of the primary units can be based on topographic features or other suitable criteria, as deemed necessary.

It must be emphasized that the sampling intensity for vegetation classification is generally too low to accurately map vegetation units according to stands because as few as four stands can represent a vegetation unit. The stratification process is, in practice, the process by which vegetation units are primarily demarcated and mapped, but can be modified and supported by the classification.

### 4.1.5 Stand location

An example of output from the program PHYTOLOC is given in Table 4.1. The stand location reference, taken as the stand

centre, is given in degrees, minutes and seconds. The x-y co-ordinates refer to the grid overlay intersection points for transfer to the relevant map. The PHYTOLOC program has been included in the PHYTOTAB-PC program package.

Stand location in the field need not be precise for classification purposes, when working at small scales, because of the random location of stands. However, comparisons with the program SIDA (section 4.2.5.2) showed that greater precision in locating the stand centre in the field was required, than could be obtained with simple visual estimation, if predicted habitat data were to correspond with that of the stand. Stand location was improved by using an altimeter to verify the contour position in the field. An optical rangefinder with a 2 km limit, used to improve stand location, proved inadequate in terms of accuracy and range.

Geographic positioning by satellite systems (GPS) should, in the future, overcome the problems of stand location. The price of such systems have decreased considerably to below R10 000 and the size has also decreased, being somewhat larger than a pocket calculator. Such a system will not only show the co-ordinates of the current position but can indicate the direction and distance to the required position.

Precise stand location will also be required, in the future, when use is made of Geographic Information Systems (GIS) for obtaining habitat data and incorporating vegetation sample sites in such systems.

### 4.1.6. Sampling unit area

Sampling unit area commensurate with a species richness of 12 species per m² is 2,5 x 5 m (section 3.1.6), determined with the sample/stand dimension utility included in the PHYTOTAB-PC program package. Sample area, for each stand in the main study area, is, therefore, a minimum of 50 m² (four 12,5 $m^2$ sampling units) or 0,025% of the 20 ha stand area. Species sampled, however, represent only about 13% (40 species out of 274) of the species present in the stand based on a species count in a representative 20 ha stand. The total canopy cover, however, represented by the species sampled is estimated to be about 95% of the total canopy cover of all the species present, based on the estimated canopy cover of each species during the species count. It must be emphasized that the sampling unit dimensions illustrated here refer to the minimum dimensions for a particular scale and for a particular species richness. Increase in sampling unit area could improve the constancy of species in a matrix, but decrease in area is likely to affect the classification.

Sampling unit area is not sample size because area is not what is being sampled. Species presence is the attribute of the samples. A minimum of four stands each with four sampling units, could, in statistical terms, be considered insufficient replication for a normal distribution (Freund & Williams 1958) within a

TABLE 4.2. - The range of sampling units per stand in the main study area

| | Number of sampling units per stand | | | |
|---|---|---|---|---|
| | 4 | 5 | 6 | 7 |
| Number of stands | 50 | 9 | 3 | 1 |
| Percentage of total | 79,4 | 14,3 | 4,7 | 1,6 |

TABLE 4.3. - PHYTOLOC output for location of sampling units where the x- co-ordinate represents direction (degrees); and the y- co-ordinate represents distance from the stand centre (m)

| COORD NO., | X-AXIS, | Y-AXIS |
|---|---|---|
| 1 | X-AX= 121 | Y-AX= 181 |
| 2 | X-AX= 227 | Y-AX= 114 |
| 3 | X-AX= 168 | Y-AX= 176 |
| 4 | X-AX= 53 | Y-AX= 88 |
| 5 | X-AX= 5 | Y-AX= 71 |
| 6 | X-AX= 166 | Y-AX= 138 |
| 7 | X-AX= 230 | Y-AX= 159 |
| 8 | X-AX= 209 | Y-AX= 81 |
| 9 | X-AX= 149 | Y-AX= 118 |
| 10 | X-AX= 294 | Y-AX= 194 |
| 11 | X-AX= 285 | Y-AX= 46 |
| 12 | X-AX= 80 | Y-AX= 21 |
| 13 | X-AX= 320 | Y-AX= 106 |
| 14 | X-AX= 252 | Y-AX= 24 |
| 15 | X-AX= 69 | Y-AX= 96 |
| 16 | X-AX= 281 | Y-AX= 235 |
| 17 | X-AX= 203 | Y-AX= 236 |
| 18 | X-AX= 242 | Y-AX= 102 |
| 19 | X-AX= 106 | Y-AX= 193 |
| 20 | X-AX= 252 | Y-AX= 17 |
| 21 | X-AX= 196 | Y-AX= 120 |
| 22 | X-AX= 2 | Y-AX= 23 |

plant community. This would often preclude statistical tests based on normal distributions. The sample, however, is not designed for statistical comparisons but to determine those species which best characterize the community and those responsible for the most significant portion of the vegetation cover. The test for the adequacy of the sample should, therefore, be scientific validity and not necessarily statistical validity. By scientific validity is meant that the processes should be repeatable by independent observers.

## 4.2 *FIELD SAMPLING*

Because sampling is ongoing the results pertaining to field sampling are examples rather than a synopsis of all the processes. The number and percentage of total, of the sampling units for all stands is given in Table 4.2.

The methods used in this study for field sampling are extremely rigorous. This confines thought and observation in the field chiefly to sampling units. The opposite extreme, is descriptive accounts of vegetation with no explicit methodology, such as Edwards (1967). In such accounts observations are not restricted and many sound conclusions have been derived. The ideal would be to utilize the best of both approaches.

### 4.2.1 Sampling unit location

Table 4.3 shows an example of the output from the program PHYTOLOC

for random sampling unit location. Position of the reference corner, for each sampling unit within the stand, is in relation to the stand centre. The greatest disadvantage in subsampling the stand, using quadrats, is in the time taken to locate, mark and record such subsamples. It was seldom that two stands could be completed in a single day.

The stand as defined in this study raises interesting possibilities regarding sampling unit location. Apart from subsampling, as described for small scale work, representative samples can be used for large scale work. Furthermore, it is conceivable that point methods could also be used within the defined stand context, thereby permitting comparison between point and quadrat data. Obviously, the number of points within a stand should result in a comparable number of species with that obtained with quadrats. A plotless method could also be used to determine the species representative of a stand. Such a method could make use of the plant number scale, whereby, species with cover greater than, say 0,05% or less than 40 crown diameters apart could be recorded within the stand. Thus the ideal of an informal sampling approach coupled with objective stand dimensions and location could be achieved. In this case the location of sampling units would not be relevant and considerable field time could be saved. The problem of minimum species area would also fall away. Hypothesis ii (section 1.3) would, therefore, be irrelevant as minimum sampling area would not be applicable.

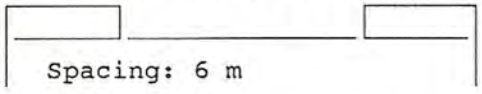
### 4.2.2 Plant identification and verification

The criteria for plant identification in the field according to specimens collected are given in Tables 4.4 to 4.8 (back pocket). The same characters and character states used for plant identification have been used for identification of the families represented by the specimens collected (Table 4.9, back pocket).

The initial input required for the construction of the plant identification key is time-consuming. It could be argued that the benefits of validating identification in this manner do not warrant the additional effort required. However, the benefits are increased by direct knowledge transfer. Van Staden (1992) used that portion of the key relevant to his study area for plant identifications, thereby reducing his own input. It is unfortunate that knowledge gained in field identification of plants cannot be easily transferred. This method goes some way towards solving that problem. The method is also very useful for training in plant identification. This is probably the first study in vegetation ecology where the criteria for plant identification in the field are given explicitly and comprehensively. The key to the families in the study area, although useful for field use, is unlikely to be of any taxonomic significance. This, nevertheless, illustrates the potential of the programs.

A camera with a data back, for imprinting reference numbers on slides, would be a decided advantage for numbering slides of plant specimens and stands, in the field. Use of a blackboard with

Acacia caffra
Community/relevè: 1
Recorded cover: 25.8%
Derived cover 25%
Mean crown diameter: 3.05 m
Individual/ha: 353
m sq/individual: 28.31 m sq
Spacing:centre-centre: 6 m
Canopy radius: 1.52 m
Canopy-canopy gap: 2.96 m




Acacia caffra
Community/relevè: 2
Recorded cover: 0.91%
Derived cover 1%
Mean crown diameter: 3.05 m
Individual/ha: 12
m sq/individual: 802.87 m sq
Spacing:centre-centre: 31.97 m
Canopy radius: 1.52 m
Canopy-canopy gap: 28.93 m

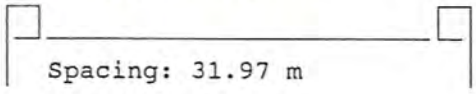



FIGURE 4.1. - Example of SPECODA output showing cover data for one crown and two cover classes.

chalked numbers for this purming and cumbersome.

4.2.3 Species cover

Examples of illustrated species cover using the program SPECODA for selected species are given in Figure 4.1. The calculations used in this program are included in the processing facility in the PHYTOTAB-PC program package. A comparison of total species cover with cover determined according to vegetation height classes for a stand should result in the following:

a) total species cover should be greater than the cover of the height class with the least cover; and
b) total species cover should be less than the sum of the cover for all height classes.

Cover estimations using the Domin-Krajina cover-abundance scale (Mueller-Dombois & Ellenberg 1974) often resulted in total species cover greatly exceeding these limits. Estimations with the plant number scale (Westfall & Panagos 1988) are within these limits.

Although fewer class intervals could enhance cover pattern on a matrix, the effectiveness of the plant number scale for estimating cover is demonstrated by Van Staden (1992). Precision is according to a whole plant. It is unlikely that greater precision would be required. However, less precision could influence results of the community composition analysis. This method also has potential for monitoring individual species change. Permanently marking transect corners would allow monitoring by merely counting individuals at required periods. In this case, the transect refers to the area

required for counting species numbers (section 3.2.3.2). Changes caused by defoliation or increases due to plant growth on the other hand, could be detected by determining the increase or decrease in transect area required for a particular species.

The over- and under-estimates obtained using the Domin-Krajina cover-abundance scale are attributed to the static position often adopted by the observer, where:

a) an adequate sample for cover estimation was often obscured by vegetation leading to under-estimation; and
b) local clumping often resulted in an over-estimation.

The plant number scale in contrast necessitates that the observer moves along a transect related to the crown diameter of a plant species. It is also doubtful whether or not summation of midpoints of large class intervals, such as found in the Domin-Krajina cover-abundance scale, can approximate actual cover.

The plant number scale method is ideally suited to informal stand sampling which would also allow for observations on species selection for monitoring to be made subjectively at time of sampling.

The potential of the species spacing illustrations and species density (Figure 4.1) was not explored. It is conceivable that these derivatives of the plant number scale could be used to examine plant spatial requirements, competition between species as well as species reactions to environmental gradients. The plant number scale also complies fully with the requirements of a scale

TABLE 4.10. - PHYTOCAP output for a selected stand showing species present (collector's number) and cover (symbol) in each sub-quadrat. Numbers preceded by "0" are line numbers followed by a number to which the first digit refers to the sub-quadrat and the last three to the stand. Cover symbols are those of the plant number scale

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 001 1047 | | 004 2047 | | 007 3047 | | 010 4047 | |
| 2149 | C | 2149 | 1 | 2297 | + | 2297 | D |
| 2297 | A | 2240 | 3 | 2053 | F | 2240 | 2 |
| 2053 | 3 | 2192 | + | 2154 | 1 | 2149 | 8 |
| 2157 | 1 | 2131 | 2 | 2131 | 7 | 2066 | 1 |
| 2192 | + | 2132 | + | 2132 | 3 | 2131 | 5 |
| 2039 | 3 | 2045 | 1 | 2192 | 1 | 2039 | 2 |
| 2131 | 1 | 2043 | + | 2229 | + | 2132 | 3 |
| 2135 | A | 2250 | + | 2194 | 4 | 2192 | 1 |
| 002 1047 | | 005 2047 | | 008 3047 | | 011 4047 | |
| 2073 | + | 2078 | 7 | 2039 | 1 | 2241 | 3 |
| 2005 | + | 2077 | 3 | 2041 | 2 | 2004 | 2 |
| 2194 | 1 | 2167 | 6 | 2077 | 2 | 2078 | 5 |
| 2165 | A | 2004 | 2 | 2008 | 8 | 2165 | 5 |
| 2241 | B | 2241 | 1 | 2165 | 2 | 2008 | 1 |
| 2167 | 5 | 2012 | 7 | 2078 | 5 | 2003 | + |
| 2077 | 5 | 2243 | 2 | 2116 | 1 | 2167 | 3 |
| 2200 | 2 | 2074 | 3 | 2167 | 6 | | |
| 003 1047 | | 006 2047 | | 009 3047 | | | |
| 2012 | 4 | 2128 | 1 | 2223 | 1 | | |
| | | 2144 | 1 | 2004 | 3 | | |

TABLE 4.11. - PHYTOFORM output for the stand in the previous Table showing conversion of data to PHYTOTAB mainframe format. Number of species = 35. Cumulative cover = 62.37%

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 001 | 00472149 | 72297 | 82053 | 82157 | +2192 | 12039 | 22131 | 42135 5 |
| 002 | 00472073 | +2005 | +2194 | 22165 | 62241 | 62167 | 52077 | 32200 1 |
| 003 | 00472012 | 42240 | 22132 | 32045 | +2043 | +2250 | +2078 | 52004 2 |
| 004 | 00472243 | 12874 | 12128 | +2144 | +2154 | +2229 | +2008 | 42116 + |
| 005 | 00472223 | +2066 | +2003 | + | | | | |

according to Londo (1976) (section 3.2.3).

Crown cover estimations are preferred to basal cover estimations because, apart from the requirements of the Braun-Blanquet approach, more factors can be related to crown cover than basal cover which inherently contains no more information than that which can be derived from species frequency. For example, crown cover can relate to a) degree of soil protection; b) utilizable material within height classes; and c) competitiveness between similar size species.

### 4.2.4 Floristic data recording

Examples of sampling unit data using the PHYTOCAP program are given in Table 4.10. Conversion of these data to stand data using the PHYTOFORM program are shown in Table 4.11. It is doubtful whether computerized field data capture is advantageous for floristic data input. The transfer programs are slow and the computer is an additional burden in the field. Additionally it is generally quicker to use pencil and paper in the field for these recordings than single finger typing on the miniaturized keyboards. For these reasons neither of these programs are included in the PHYTOTAB-PC program package. It is, furthermore, suggested that greater efficiency can be obtained in the field by recording floristic data on field sheets, with provision for relevant casual observations, and that the data be captured on a laptop computer, loaded with the PHYTOTAB-PC programs, daily after fieldwork.

If a classification is the aim of a study then species presence only is the minimum floristic data required. PHYTOTAB-PC does not require cover values for classification or for synoptic table generation. Ordinations of communities based on synoptic tables also do not require cover values.

A quick visual assessment of dominance from a phytosociological table requires a scale with few cover classes. Too much detail would require numerical treatment of the data for understanding. Such treatment could imply a precision greater than that possible with cover estimation techniques used, such as the Domin-Krajina cover-abundance scale. This may not be too important if a visual assessment of dominance only, is required. If plant spacing and density in terms of individuals per unit area, are required then the plant number scale is highly convenient because only the recording of the crown diameter class is additionally necessary. This value is, in any case, necessary for determining transect length.

Any comparison of plant species should require categorization because of the disparity in plant species. A simple categorization such as growth form classes can be adequate. The system of growth form categorization used in this study has the advantage of being related to height classes. This permits a separate structural analysis of vegetation to be replaced by a growth form/cover analysis with little loss of information. Additional input is the growth form code.

Any additional information recorded would be dependent on the aims of a particular study. However, it must be emphasized that descriptive data such as vitality and sociability are difficult to treat numerically and their value is often lost. It is far easier to incorporate descriptive data into a small data set than a large data set which can only be reduced numerically.

If an informal method of stand sampling is adopted then casual observations could be relevant. A danger can exist of an intermittent phenomenon being recorded when first observed but its occurrence in prior situations could have been overlooked. This problem is overcome with a pre-determined list of considerations for observation.

A full numerical analysis of data using the PHYTOTAB-PC programs requires species presence together with cover code, crown diameter code and growth form code to be recorded in the field.

### 4.2.5 Habitat data

In the main study area, eleven parameters relating to stands, eleven parameters relating to sampling units (quadrats) and twelve parameters derived from 1:50 000 Topo series maps (section 3.2.5.2) were recorded, apart from the general requirements of stand description.

The general requirements for describing a stand sample are:

TABLE 4.12. - HABIMEAN output for stand 47 showing conversion of recorded subquadrat habitat data to stand data

```
Stand number: 47
 Aspect vector: 294 degrees
 Slope (mean): 0 degrees
 Litter cover: 2%
 Litter depth: 2 mm
 Soil depth (min): 1000 mm
 Soil depth (mean): 1200 mm
 Soil depth (max): >1200 mm
 Soil colour (mean): 10YR 4/2
 Soil texture (% clay): 4%
 Soil form: SP-100%
 Surface rock cover: 0%
 Surface compaction: 132.38 kPa
 Relative herbaceous biomass: 35 mm*
```

*measured as disc pasture meter drop height

a) stand number, starting at 1 and increasing consecutively for each stand sampled within a study area or data set. This is the unique number for each stand required by the PHYTOTAB-PC programs. In the abstraction of communities in the phytosociological tables, stand or sample numbers are referred to as relevè numbers (Mueller-Dombois & Ellenberg 1974);

b) date of sampling the stand, being the temporal reference of the stand; and

c) sample co-ordinates of latitude and longitude in degrees, minutes and seconds, being the spatial reference of the stand. The program PHYTOLOC (section 3.1.5) determines location and co-ordinates to fractions of a second so that recording of this information is simple. Locating the point on the ground, however, could cause problems (section 4.1.5).

4.2.5.1 *Field data*

Numerical data describing the stand include altitude, exposure and temperature. Mappable or spatial data include lithostratigraphy, geomorphology, vegetation structure and land use. Non-spatial, descriptive data include grazing, browsing, erosion and fire. With the exception of soil form, sampling unit data recorded are numerical. Examples of the averaging of sampling unit data using the HABIMEAN program for a selected stand are given in Table 4.12. This program is not included in the PHYTOTAB-PC program package because its use is restricted to the habitat parameters used in this study, whereas, the decision as to what parameters to record in a study, can differ widely.

The results of the program HABIMEAN (Table 4.12) are mainly arithmetic means, except for aspect, soil form and soil colour. Aspect is the vector of aspects with magnitude slopes. The main influence of aspect modified by slope is thus taken into account. Combination of a north and south aspect, for example, where the slopes are 10° and 2° respectively would result in a north aspect with a mean slope of 6°. This is a possible solution to the problem of averaging aspects where a single numerical value is required for correlation purposes and the effect of slope must be included. However, the effectiveness of such vectors has not been shown and other factors such as latitude could influence the function appreciably. Soil forms are not averaged but the percentage occurrence of a soil form for the sampling units of a stand are calculated. For soil colour the individual components of hue, value and chroma (Munsell Soil Color Charts 1954) are averaged to reflect an average colour for the stand. Soil colour is, therefore, a numerical value, according to the Munsell notations, which can be treated accordingly.

The argument that descriptive data is difficult to include in a numerical treatment of a large data set (section 4.2.4) partially applies to habitat data. The exception is spatial descriptive data such as geology and soil type which can be visually correlated with vegetation units as overlays or manipulated as coverages in a Geographic Information System. Descriptive, non-spatial habitat information, such as the occurrence of fire and estimation of grazing intensity, would, therefore, have a low relevance in large data sets.

(a)

HEADER

Stand no: ... Grid no: .....

Altitude (m)

Aspect<——— Exposure | MAR (mm) ———

(deg) Mean soil depth (mm) (deg) | RAM (mm)

Topo profile: (from drainage to watershed)

Landscape slope (deg)

Stand slope (deg)

Scale (in relation to stand diameter)

Geomorphology:

Drainage:

(b)

Stand no: 47 Grid no: 2428AA

1200 | 607

0 <——— 180 | ———

419 | 200

Topo profile:-

0

———

0

Scale: 500 m

Geomorphology: Flat (B)

Drainage: No flow -C

FIGURE. 4.2. - SIDA output for stand 47 showing header form with explanations (a) and data (b).

TABLE 4.13. - Statistical output for all relevès showing correlations between SIDA data (x-axis) and the corresponding field data (y-axis) for a) altitude

a)

| | | | |
|---|---|---|---|
| Minimum | X= 890 | Y= 890 | Linear regression (y=xb+c) |
| Maximum | X= 1760 | Y= 1775 | Slope (b )= 1.005 |
| Range | X= 870 | Y= 885 | Angle of slope= 45.150 degrees |
| Total | X= 81260 | Y= 81080 | Y-axis interception (c )=-9.671 |
| Mean | X= 1289.84 | Y= 1286.98 | Correlation coefficient (r )= .995 |
| Median | X= 1300 | Y= 1280 | Regression variance= 463.843 |
| Midrange | X= 1325 | Y= 1332.5 | Standard error of the estimate= 21.537 |
| Harmonic mean | X= 1248.31 | Y= 1244.65 | |
| Mean deviation | X= 4.759 | Y= 4.714 | |
| Variance | X= 53495.125 | Y= 54518.179 | |
| Standard deviation | X= 231.290 | Y= 233.491 | |
| Coefficient of variation | X= 17.931% | Y= 18.142% | |
| Standard error of the mean | X= 29.139 | Y= 29.417 | |

Scatter diagram

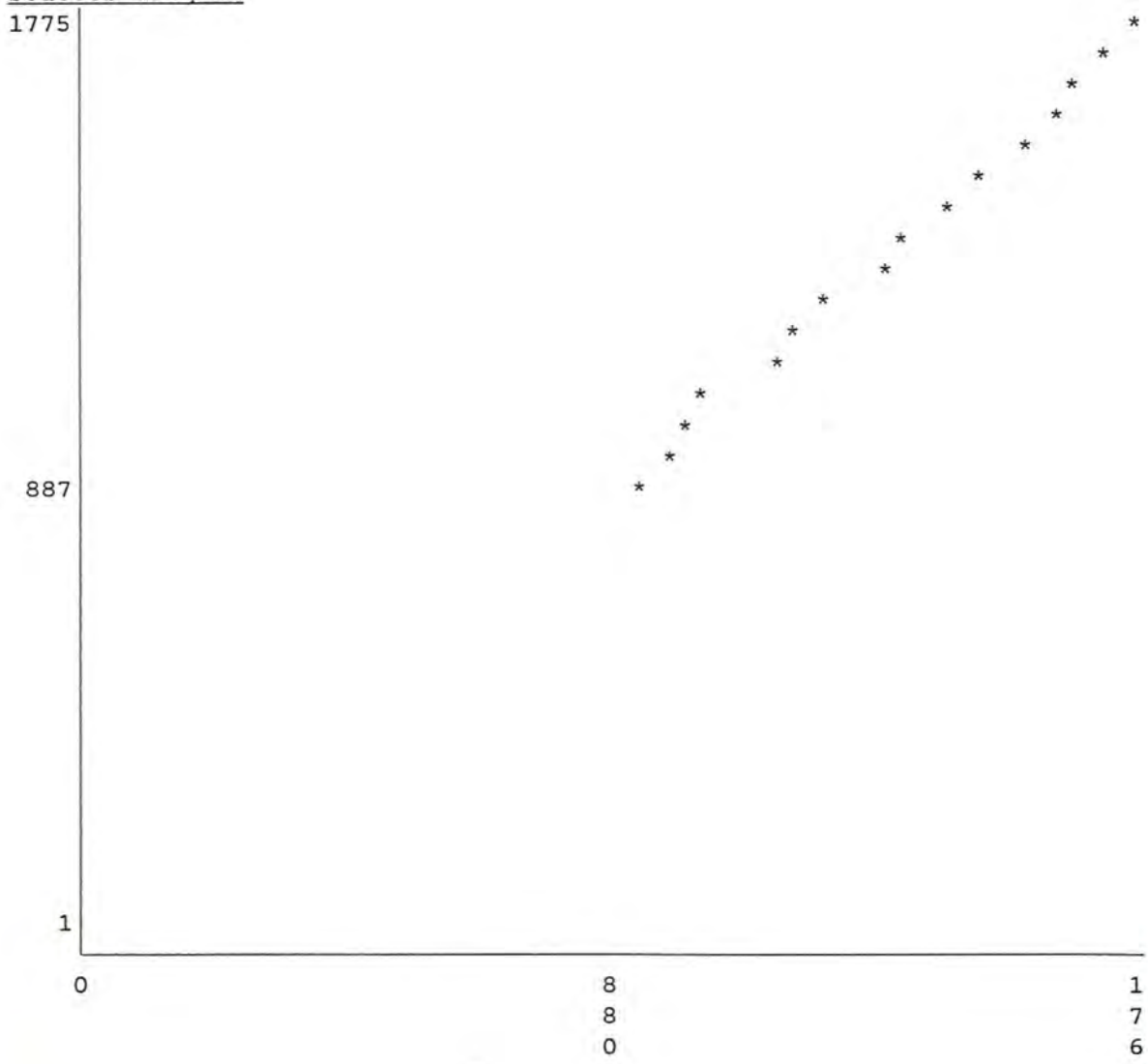


TABLE 4.13 (continued). - Statistical output for all relevès showing correlations between SIDA data (x-axis) and the corresponding field data (y-axis) for b) aspect

b)

| | | |
|---|---|---|
| Minimum X= 0 | Y= 0 | Linear regression (y=xb+c) |
| Maximum X= 444 | Y= 448 | Slope (b )= .801 |
| Range X= 444 | Y= 448 | Angle of slope= 38.724 degrees |
| Total X= 12875 | Y= 14755 | Y-axis interception (c )= 70.33 |
| Mean X= 204.36 | Y= 234.20 | Correlation coefficient (r )= .801 |
| Median X= 231 | Y= 274 | Regression variance= 6706.697 |
| Midrange X= 222 | Y= 224 | Standard error of the estimate= 81.894 |
| Geometric mean X= 0 | Y= 0 | |
| Mean deviation X= 3.243 | Y= 3.717 | |
| Variance X= 18412.912 | Y= 18437.716 | |
| Standard deviation X= 135.694 | Y= 135.785 | |
| Coefficient of variation X= 66.397 % | Y= 57.976 % | |
| Standard error of the mean X= 17.095 | Y= 17.107 | |

Scatter diagram

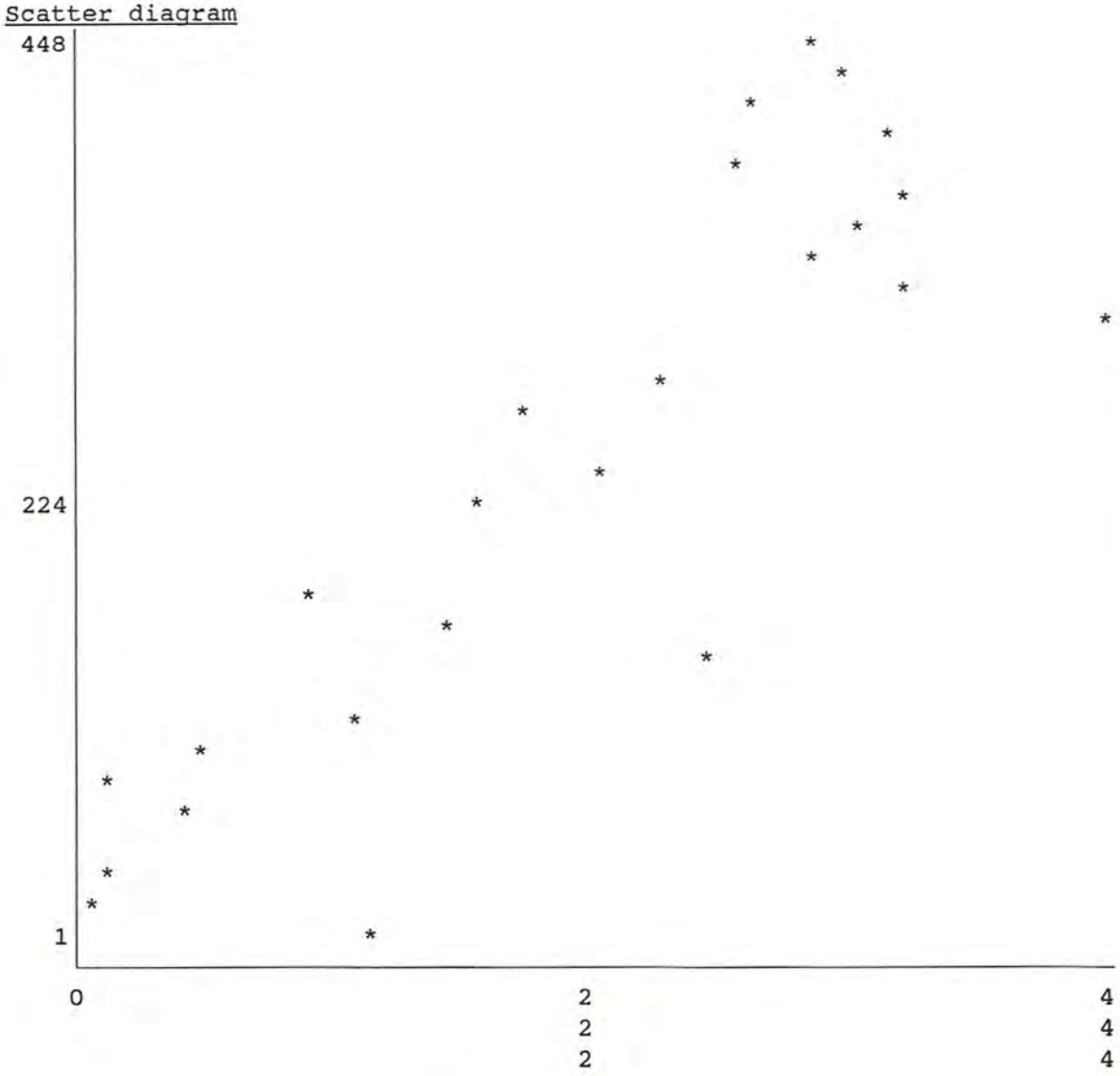


TABLE 4.13 (continued). - Statistical output for all relevès showing correlations between SIDA data (x-axis) and the corresponding field data (y-axis) for c) slope

c)

| | X | Y |
|---|---|---|
| Minimum | 0 | 0 |
| Maximum | 180 | 180 |
| Range | 23 | 29 |
| Total | 11127 | 10993 |
| Mean | 176.61 | 174.49 |
| Median | 178 | 176 |
| Midrange | 168.5 | 165.5 |
| Harmonic mean | 176.489 | 174.284 |
| Mean deviation | .0006 | .0039 |
| Variance | 21.788 | 33.899 |
| Standard deviation | 4.667 | 5.822 |
| Coefficient of variation | 2.642 % | 3.336 % |
| Standard error of the mean | .588 | .733 |

Linear regression (y=xb+c)

Slope (b)= .707
Angle of slope= 35.281 degrees
Y-axis interception (c)= 49.523
Correlation coefficient (r)= .567
Regression variance= 23.368
Standard error of the estimate= 4.834

Scatter diagram

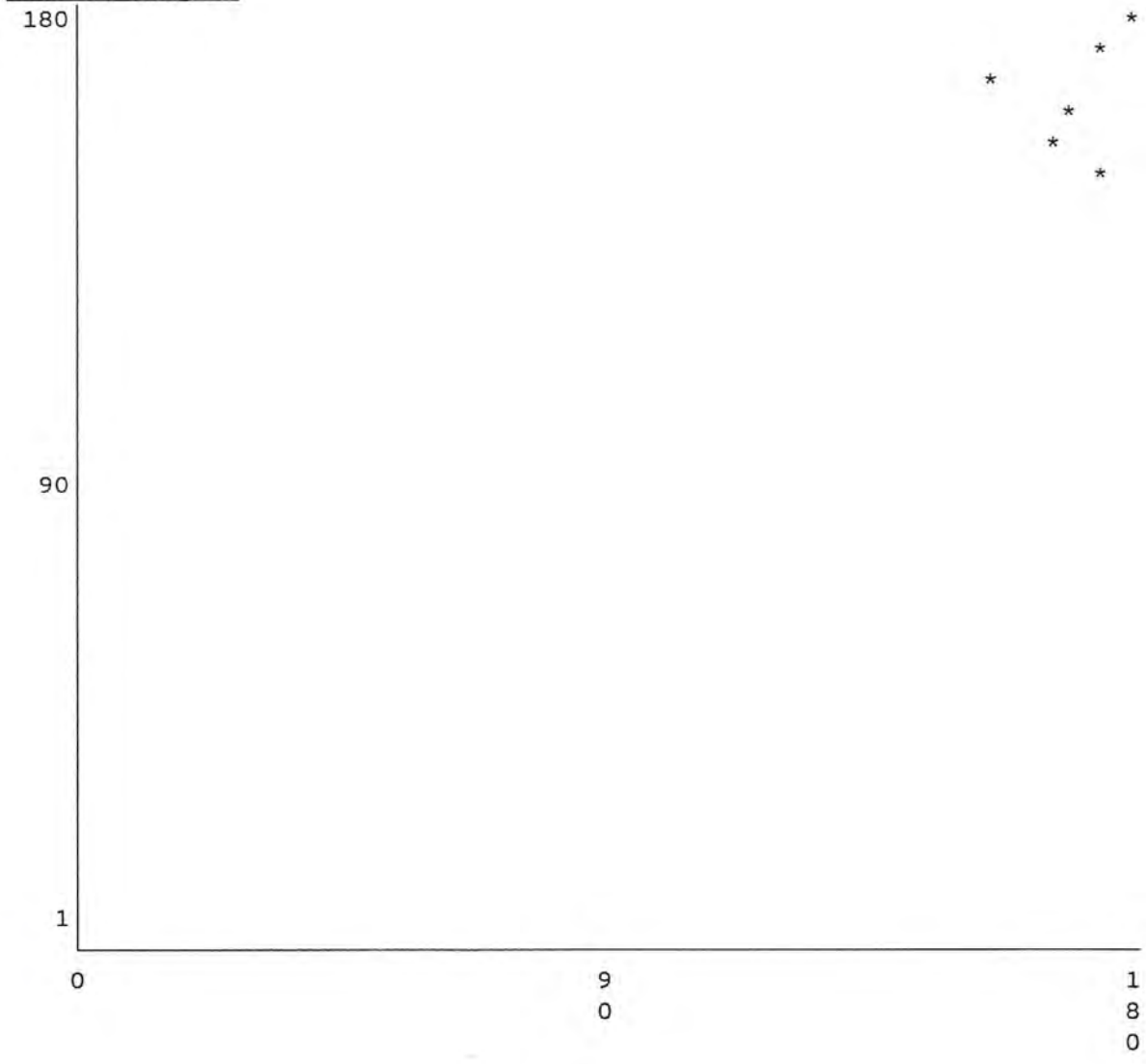


TABLE 4.13 (continued). - Statistical output for all relevès showing correlations between SIDA data (x-axis) and the corresponding field data (y-axis) for d) exposure

d)

| | | |
|---|---|---|
| Minimum X= 157 | Y= 151 | Linear regression (y=xb+c) |
| Maximum X= 180 | Y= 180 | Slope (b)= .707 |
| Range X= 23 | Y= 29 | Angle of slope= 35.281 degrees |
| Total X= 11127 | Y= 10993 | Y-axis interception (c)= 49.523 |
| Mean X= 176.61 | Y= 174.49 | Correlation coefficient (r)= .567 |
| Median X= 178 | Y= 176 | Regression variance= 23.368 |
| Midrange X= 168.5 | Y= 165.5 | Standard error of the estimate= 4.834 |
| Harmonic mean X= 176.489 | Y= 174.284 | |
| Mean deviation X= .0006 | Y= .0039 | |
| Variance X= 21.788 | Y= 33.899 | |
| Standard deviation X= 4.667 | Y= 5.822 | |
| Coefficient of variation X= 2.642 % | Y= 3.336 % | |
| Standard error of the mean X= .588 | Y= .733 | |

Scatter diagram

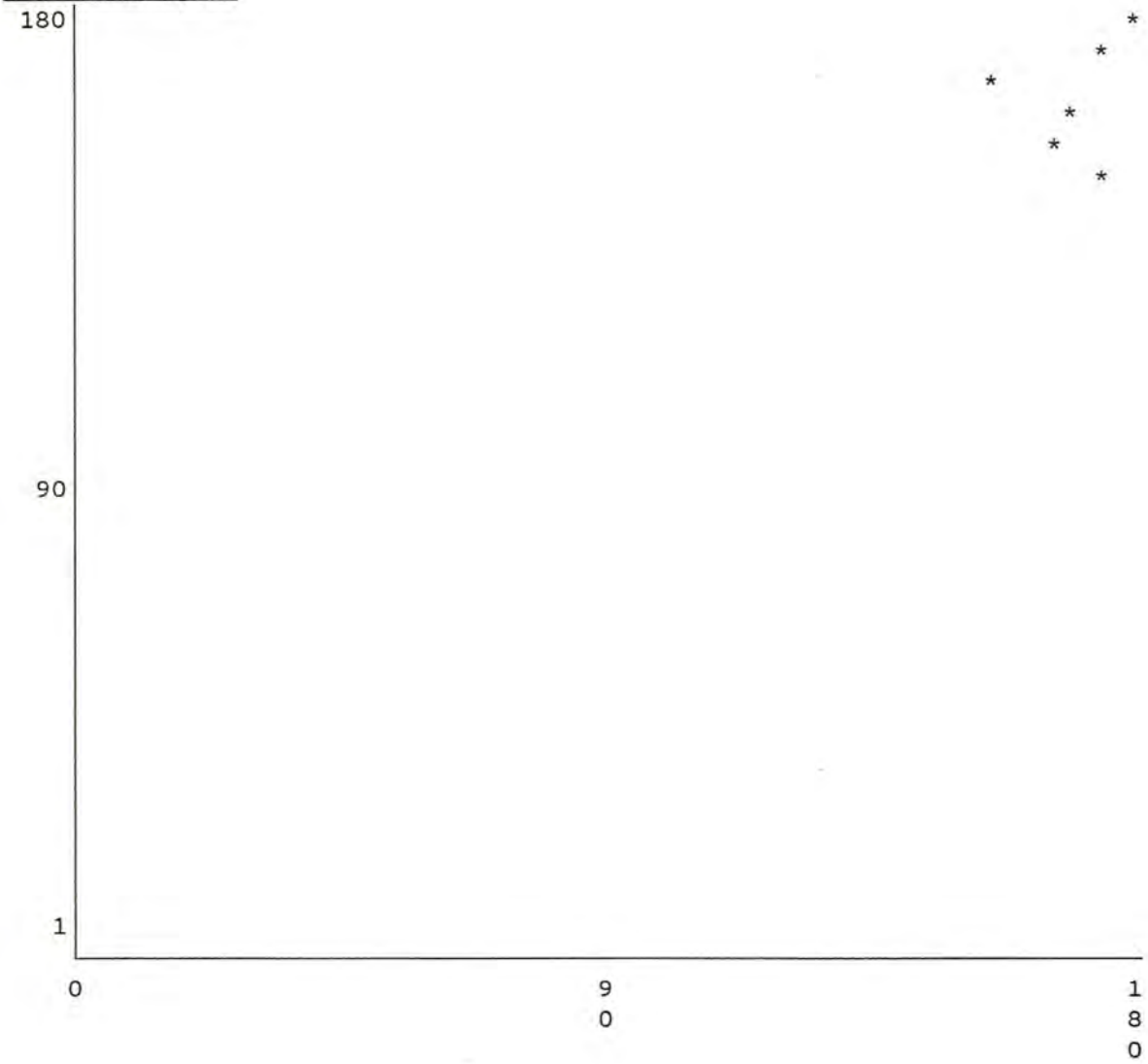


TABLE 4.13 (continued). - Statistical output for all relevès showing correlations between SIDA data (x-axis) and the corresponding field data (y-axis) for e) soil depth

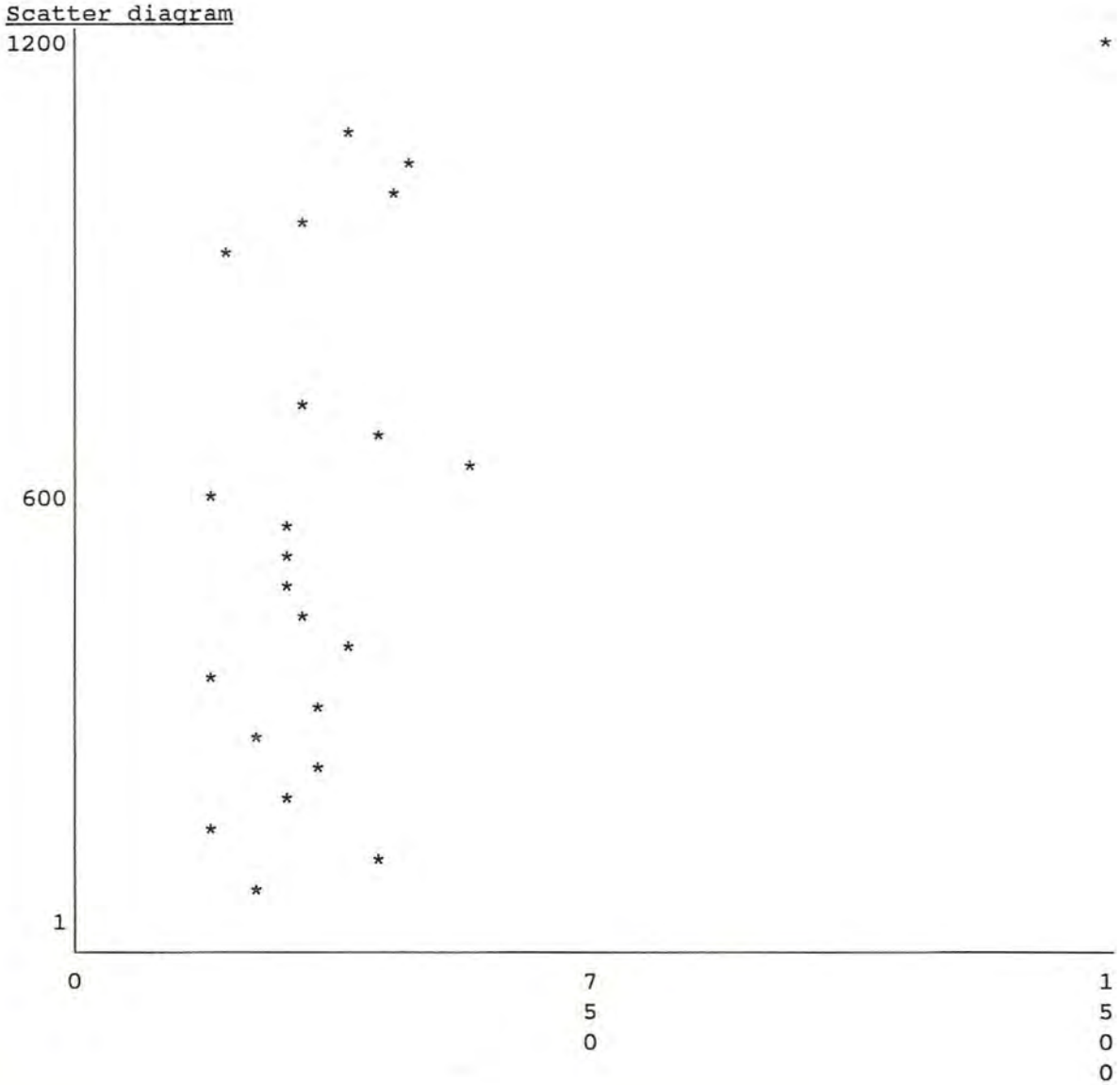
e)

| | X | Y |
|---|---|---|
| Minimum | 75 | 90 |
| Maximum | 1500 | 1200 |
| Range | 1425 | 1110 |
| Total | 23915 | 34433 |
| Mean | 379.60 | 546.55 |
| Median | 349 | 413 |
| Midrange | 787.5 | 645 |
| Harmonic mean | 296.425 | 261.602 |
| Mean deviation | 1.942 | 8.197 |
| Variance | 56192.152 | 177586.609 |
| Standard deviation | 237.048 | 421.410 |
| Coefficient of variation | 62.446 % | 77.102 % |
| Standard error of the mean | 29.865 | 53.092 |

Linear regression (y=xb+c)

Slope (b)= .678
Angle of slope= 34.159 degrees
Y-axis interception (c)= 288.967
Correlation coefficient (r)= .381
Regression variance= 154199.5
Standard error of the estimate= 392.682

Scatter diagram



Based on observations in this study as well as Westfall (1981) and Van Staden (1992) the two main factors responsible for vegetation unit differentiation, in areas where moisture is a limiting factor and data are not readily obtainable elsewhere (section 4.2.5.2), are soil texture and soil depth. Determination of the former using both the "sausage" and "finger test" methods (section 3.2.5.2) appears adequate. It is, however, unreasonable to expect that a random sample of four auger holes could always be representative of the soil depth of a 20 ha stand. Increasing the number of auger holes could improve correlations but the number required to satisfy statistical requirements is impracticable. A more efficient method of soil depth determination is required.

4.2.5.2 *Derived data*

Examples of habitat data derived from 1:50 000 Topo series maps using the SIDA program are given in Figure 4.2. Comparisons of SIDA output with the corresponding variables recorded in the field using the program MINISTAT are given in Table 4.13. Correlation of 355° and 5° aspect, although numerically disparate are not very dissimilar in terms of direction, being only 10° apart. The following transformations were applied, for comparison to overcome this problem:

a) for SIDA values between 360° and 90° and relevè values between 270° and 360° add 360° to SIDA value;
b) for relevè values between 360° and 90° and SIDA values between 270° and 360° add 360° to relevè value; and

c) if SIDA or relevè values are between 90° and 270° then 360° is taken as 0°.

The best correlation co-efficient (r=0,99) was obtained with altitude because the same source was used in both cases. Aspect, slope, exposure and soil depth gave correlation co-efficients of 0,80; 0,67; 0,56 and 0,38 respectively. That better correlation co-efficients were not obtained, could relate to the shortcomings in the field sampling methods, where sample size was inadequate, or incorrect stand location, in the field. For example, the discrepancies between SIDA data and field habitat data for altitude can be attributed to imprecise stand location, because both recordings were derived from the same source. It is also likely that the incorrect location of certain stands could have affected the correlations of other parameters (Table 4.13). Specific problems relating to field data measurement include: a) local variation in aspect, slope and soil depth; b) vegetation obscuring the horizon for exposure determinations; and c) subsurface rocks and gravel layers for soil depth determinations.

The soil depth determinations using the SIDA program are, furthermore, based mainly on degree of slope. This implies that all level ground, not on summits, would be greater than 1 500 mm in depth. Clearly this is not the case, hence it is suggested that soil depth be recorded in the field despite the limitations associated with this measurement. The good correlation between mean annual rainfall and altitude and latitude is applicable only to the main study area. Van Staden (1992) found that altitude alone was suf-

ficient and the SIDA program was adapted accordingly for that study area. Rainfall correlations should, therefore, be done on a local basis for stand interpolation.

Another source for derived rainfall data using a similar rationale namely, altitude and topography, are the data available from the Computing Centre for Water Research, University of Natal, Pietermaritzburg (Dent *et al.* 1987). These data, however, may not be sufficiently precise for stand purposes because they are only available on a one minute grid basis.

An advantage of the method of determining exposure described in this study is the effect of kloof orientation on exposure. Although such a situation was not sampled in this study, a kloof with a north-south orientation would be exposed to insolation for a far shorter duration than a kloof with an east-west orientation. These differences can be detected with the method described. The significance of such differences has yet to be assessed. It, furthermore, appears reasonable to consider exposure in terms of its components because the components are easier to quantify. If, by exposure is meant exposure to sun and wind, then these two components should be considered separately. Hence, exposure in this account is taken to mean exposure to insolation only.

The SIDA parameter of relative available moisture (RAM) is unlikely to be of much significance because of the large number of components used to derive the values. The algorithms are

TABLE 4.14. - PHYTOTAB-PC classification of a synthetic data set using both the heuristic and permutation methods. Noise is absent. Total separation units=0. Classification efficiency=100%.

| Releve number: | 00 42 | 00 81 | 00 53 | 00 76 |
|---|---|---|---|---|
| Species 1 | ++ | | | |
| Species 2 | ++ | | | |
| Species 3 | | ++ | | |
| Species 4 | | ++ | | |
| Species 5 | ++ | ++ | | |
| Species 6 | ++ | ++ | | |
| Species 7 | | ++ | ++ | |
| Species 8 | | ++ | ++ | |
| Species 9 | | | ++ | |
| Species 10 | | | ++ | |
| Species 11 | | | ++ | ++ |
| Species 12 | | | ++ | ++ |
| Species 14 | | ++ | ++ | ++ |
| Species 13 | | ++ | ++ | ++ |
| Species 15 | ++ | ++ | ++ | ++ |
| Species 16 | ++ | ++ | ++ | ++ |
| Species 19 | | | + | + |
| Species 18 | | + | + | |
| Species 17 | + | + | | |
| Species 20 | | | + | |

TABLE 4.15. - TWINSPAN classification of the synthetic data set in Table 4.14.Total separation units=21. Classification efficiency=74%.

| Releve number: | 00000000 35671248 |
|---|---|
| Species 9 | ++ |
| Species 20 | + |
| Species 19 | + + |
| Species 12 | ++++ |
| Species 11 | ++++ |
| Species 10 | ++ |
| Species 14 | +++++ + |
| Species 13 | +++++ + |
| Species 8 | ++ + + |
| Species 7 | ++ + + |
| Species 18 | + + |
| Species 16 | ++++++++ |
| Species 15 | ++++++++ |
| Species 6 | ++++ |
| Species 5 | ++++ |
| Species 4 | + + |
| Species 3 | + + |
| Species 2 | ++ |
| Species 17 | + + |
| Species 1 | ++ |

somewhat complex. A far simpler approach is effective soil wetting depth, used with good results by Van Staden (1992).

It is conceivable that for many of the parameters recorded in the field, more precise data could be obtained by using the SIDA program. This would also save field work time and allow information to be utilized which would otherwise be impracticable to record in the field, such as stand position in terms of drainage line and watershed, which is often impracticable to determine in the field. Although the SIDA program illustrates the potential of an indirect approach to recording certain habitat data, manual data input from topographic maps is extremely time-consuming. The approach is likely to be better adapted to digital terrain data and GIS processing, when such data becomes available. The SIDA programs have, accordingly, not been included in the PHYTOTAB-PC program package. However, the MINISTAT program is included in the PHYTOTAB-PC program package under the statistics utility.

## 4.3 *CLASSIFICATION*

The PHYTOTAB-PC classification results of a synthetic data set are given in Table 4.14. The data set was constructed in such a manner that noise, in the form of separation units, would be absent if correctly classified. The initial relevè sequence was random. Identical results were achieved using both the heuristic approach which includes commonality, similarity and separation unit sequencing and the permutation approach which can only be used on small data sets. In the case of the last-mentioned

TABLE 4.16. - Number sequence comparison of the grouped relevè sequences in Tables 4.14 & 4.15

a) Correspondence of relevè-groups

| Table 4.15 \ Table 4.14 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | 0 | 2 | 0 |
| 2 | 0 | 0 | 0 | 2 |
| 3 | 1 | 1 | 0 | 0 |
| 4 | 1 | 1 | 0 | 0 |

b) Percentage correspondence of relevè-groups

| Table 4.15 \ Table 4.14 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0 | 0 | 100 | 0 |
| 2 | 0 | 0 | 0 | 100 |
| 3 | 50 | 50 | 0 | 0 |
| 4 | 50 | 50 | 0 | 0 |

Mean correspondence = 67%

approach, mirror-images are excluded. Both approaches are available on the PHYTOTAB-PC program package. Noise is absent, as shown by zero separation units and classification efficiency is 100%.

These results show that the algorithms used for relevè sequencing in the PHYTOTAB-PC program package (heuristic approach) can produce results comparable with relevès being tested in each possible position (permutation approach) for small data sets. Processing time limitations, even on a mainframe computer, preclude similar tests on large data sets but it is assumed that the results would be similar. However, the user should be aware that the relevè sequence obtained using the heuristic approach does not test relevès in each possible position and that the total separation units need not necessarily be the lowest obtainable for a particular data set. Classification efficiency values, however, indicate that the heuristic approach is an improvement on all classifications tested.

Table 4.15 gives the result of a TWINSPAN (Hill 1979a) classification of the same data set used in Table 4.14, with the initial relevè sequence ranging from 1 to 8 ascending, as required. Noise is present, as shown by the 21 separation units and classification efficiency is reduced to 74%. The differences, between the two methods, are illustrated in Table 4.16 in which the grouped number sequences of both results are compared in both absolute and percentage terms, with a mean correspondence of 67%.

TABLE 4.17.- TWINSPAN classification of the synthetic data set in Table 4.14, using a random relevè input sequence. Total separation units=14. Classification efficiency=82%.

| Relevè number: | 00000000<br>18243567 |
|---|---|
| Species 3 | ++ |
| Species 4 | ++ |
| Species 5 | ++++ |
| Species 6 | ++++ |
| Species 7 | ++ ++ |
| Species 8 | ++ ++ |
| Species 13 | ++ ++++ |
| Species 14 | ++ ++++ |
| Species 15 | ++++++++ |
| Species 16 | ++++++++ |
| Species 18 | + + |
| Species 1 | ++ |
| Species 2 | ++ |
| Species 17 | ++ |
| Species 11 | ++++ |
| Species 12 | ++++ |
| Species 19 | + + |
| Species 20 | + |
| Species 9 | ++ |
| Species 10 | ++ |

The TWINSPAN results are not satisfactory in that, groups formed by relevès 4;2 and 8;1 (Table 4.14) are contraposed in the TWINSPAN classification. Furthermore, the extreme relevès (3;8) in the TWINSPAN classification are centrally positioned in Table 4.14.

Table 4.17 gives the result of a TWINSPAN classification of the same data set used in Tables 4.14 & 4.15, but with the initial relevè sequence in a random order. However, the original relevè numbers have been retained. The results differ from the previous TWINSPAN results (Table 4.15) as shown by noise present which is represented by 14 separation units and a classification efficiency of 82%. The results in Tables 4.14 & 4.17 correspond in terms of grouping of relevès because a number sequence comparison between the two relevè sequences gives a mean correspondence of 100%. However, there is lack of correspondence in the position of the relevè-groups, where the first two releve-groups are contraposed. It is noteworthy that a random initial relevè sequence for TWINSPAN gives a better result, in this case, than the required input sequence.

The data set used in these examples contains no outliers and relevè-group pattern is consistent. Worse results could be expected with TWINSPAN where outliers are present and relevè-groups contain gaps. These results show that TWINSPAN is inadequate for final classifications in terms of relevè-group definition or sequence. Care should, furthermore, be exercised when using TWINSPAN to select species upon which to group relevès.

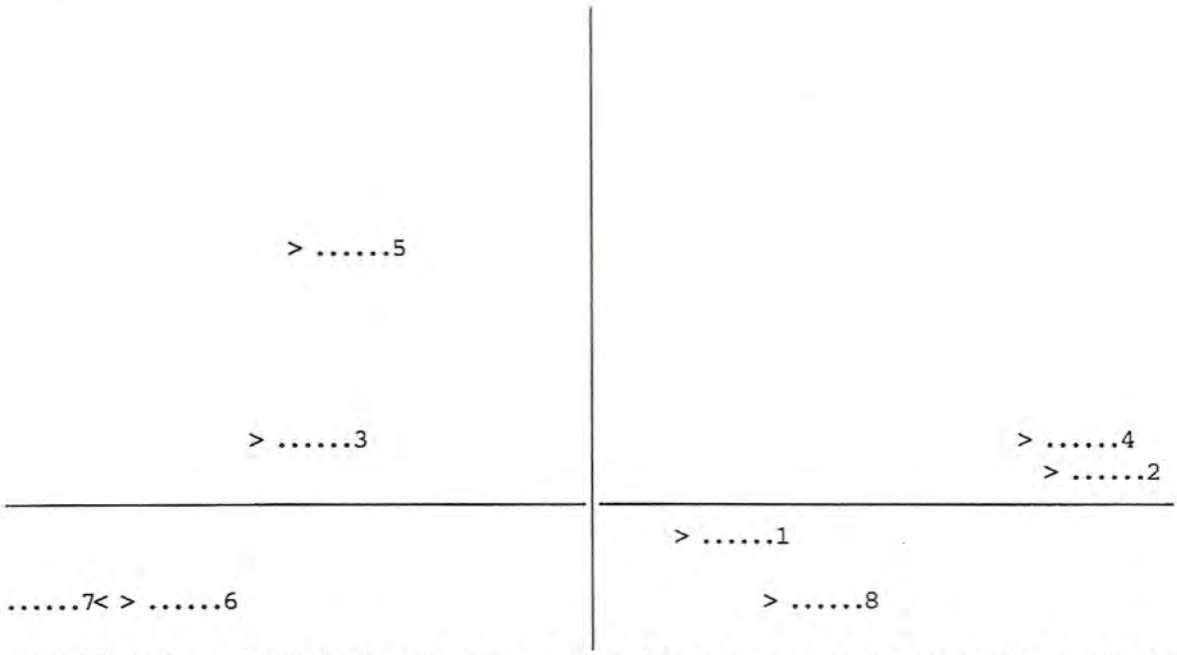



FIGURE 4.3. - DECORANA ordination of relevès using data in Table 4.14 and the CANOCO program. Arrowheads indicate position of each relevè. The horizontal axis is axis 1 and the vertical axis is axis 2.

On the other hand, the result of a DECORANA (Hill 1979b) ordination of the same data set (Table 4.14) using CANOCO (Ter Braak 1986), (Figure 4.3) shows complete correspondence in terms of grouping relevès with the groups formed in Table 4.14, as the mean correspondence between the two grouped relevè sequences is 100%. Furthermore, the relevè-groups thus formed, also occur in similar sequences in both the ordination (first axis) and the PHYTOTAB-PC classification, with the latter in reverse order. For this data set, the results of the DECORANA ordination, therefore, correspond far better with the PHYTOTAB-PC classification than with either of the TWINSPAN classifications. Changing the input sequence did not affect the DECORANA results. DECORANA, therefore, supports the PHYTOTAB-PC classification but is not suitable for classification by itself, because of the difficulty in determining relevè-groups from cluster diagrams in large data sets.

Van Staden (1992) has also shown the relevance of DECORANA ordination in analysing the components of the main environmental gradient within his study area. However, the aforementioned application of ordination was not a species by relevè ordination but a diagnostic species by community ordination. This is an ordination of the diagnostic species in the matrix, that is, those species contributing to relevè-group pattern and using the relevè-groups as relevès, which are obtained with the synoptic table. This effectively reduces noise in the form of non-diagnostic species which can often be from one third to a half of the species total and reduces redundancy in the form of relevès belonging to the same relevè-groups. Gauch (1982) mentions that excessive noise can

TABLE 4.18.- PHYTOTAB-PC classification of the first data set in the second study area. Total separation units=127. Classification efficiency=70%.

| Releve-group number: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Releve number: | 2122121 3921800 | 012 554 | 0110011100 9378212667 | 010 341 | 02 45 |
| *Helichrysum rugulosum* | 1 11 | | | | |
| *Lippia scaberrima* | 11 | 1 | | | |
| *Convolvulus sagittatus* | 11 | | | | |
| *Scabiosa columbaria* | | 111 | | | |
| *Tephrosia capensis* | | 1 | 1+ 11 1 | | |
| *Salvia runcinata* | | | 1111 | | |
| *Tragus berteronianus* | | | 111 1 | | |
| *Phyllanthus maderaspatensis* | | 1 | 11 11 | | |
| *Aristida congesta* subsp. *barbicollis* | | | 11 1 | | |
| *Eragrostis pseudosclerantha* | 1 | | 1 11 | | |
| *Helichrysum nudifolium* | | | 11 | | |
| *Tagetes minuta* | 11 | | 11 111 | 1 | |
| *Chaetacanthus* sp. | | | | 111 | |
| *Aristida congesta* subsp. *congesta* | | | 21 12 | 1 2 | |
| *Sutera* sp. | | 111 | 1 1 | 1 1 11 | |
| *Anthospermum pumilum* | 11 | 1 | 1111 1 | 11 111 | |
| *Heteropogon contortus* | 22 22 | 22 | 22 1 | 1 23 | |
| *Cymbopogon excavatus* | 3 | | 33 2 3 33 | 232 23 | |
| *Eragrostis chloromelas* | 3333223 | 333 | 3333433233 | 324 | 33 |
| *Hyparrhenia anamesa* | 33333 3 | 333 | 3333433333 | 333 | 33 |
| *Elionurus muticus* | 2222 22 | 222 | 22 2222 | 23 221 | 22 |
| *Conyza podocephala* | 1 11111 | 111 | 1111111111 | 1 | 11 |
| *Vernonia oligocephala* | 11 | 11 | 1 11 1 | 11 | 11 |
| *Hermannia* cf. *grandifolia* | 1 1 | 1 | 111 | 11 | 11 |
| *Crabbea angustifolia* | 11 | | 11 1 | | |
| *Verbena brasiliensis* | 11 | | 1 1 | | |
| *Protasparagus suaveolens* | | 1 | | | |
| *Melinis repens* | | 1 | | | |
| *Hibiscus microcarpus* | | | 1 | | |
| *Verbena tenuisecta* | | | | + | |
| *Athrixia elata* | | 1 | | | |

TABLE 4.19.- PHYTOTAB-PC classification of the second data set in the second study area. Total separation units=99. Classification efficiency=72%.

| Relevè-group number: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Relevè number: | 01100 62143 | 1121 7349 | 21 18 | 2200 2352 | 0102101120 7690580451 |
| *Chaetacanthus* sp. | 11 11 | 1 1 | | | |
| *Hermannia* cf. *grandifolia* | | 111 | | | |
| *Hibiscus microcarpus* | | 11 | | | |
| *Helichrysum nudifolium* | | | | 11 | |
| *Phyllanthus maderaspatensis* | | | | 11 | |
| *Aristida congesta* subsp. *barbicollis* | | | | | 11 111 |
| *Indigofera zeyheri* | | | | | 11 11 |
| *Sutera* sp. | | | | | 11 |
| *Themeda triandra* | | | | 1 1 | 1 1111 11 |
| *Heteropogon contortus* | | 12 | 21 2 | 2 | 2121 2 1 2 |
| *Eragrostis chloromelas* | 33323 | 3333 | 33 | 3323 | 3333233333 |
| *Elionurus muticus* | 22222 | 1221 | 21 | 2222 | 2322 22223 |
| *Hyparrhenia anamesa* | 33333 | 3333 | 33 | 3333 | 333333 333 |
| *Conyza podocephala* | 111 1 | 1111 | 11 | 1111 | 11111 1111 |
| *Trachypogon spicatus* | 111 | 1111 | 11 | 11 1 | 111111111 |
| *Vernonia oligocephala* | 11111 1 | 1 | 11 | 111 | 11111111 1 |
| *Scabiosa columbaria* | 1111 | 11 | 11 | 1111 | 111111 1 |
| *Crabbea angustifolia* | 11111 | 11 | | 1 | 111 111 |
| *Cymbopogon excavatus* | 3333 | 32 | 2 | 223 | 1 22 |
| *Brachiaria serrata* | 11 | 1111 | | 11 | 11 1 |
| *Anthospermum pumilum* | 11 | 1 | 1 | | 1 1 1 1 |
| *Tephrosia capensis* | 11 | | 1 | 1 | 11 |
| *Melinis repens* | | 1 1 | 1 | 11 | |
| *Eragrostis capensis* | | | 11 | 1 | 1 |
| *Tagetes minuta* | | 1 | 1 | 11 | |
| *Helichrysum rugulosum* | | 1 | | | |
| *Aristida congesta* subsp. *congesta* | | | | 1 | |
| *Gazania krebsiana* | 1 | | | | |
| *Dicoma zeyheri* | | | | | 1 |
| *Eragrostis racemosa* | | 1 | | | |
| *Sonchus wilmsii* | | | | + | |

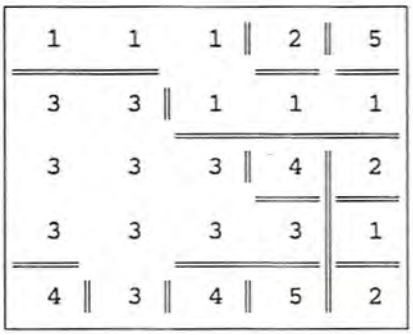



FIGURE 4.4. - Position of 2 x 2 m sampling units in the first 10 x 10 m quadrat showing relevè grouping according to the classification (Table 4.18), by relevè-group numbers in the position of each relevè. Each of the relevè-groups has a common border with the 10 x 10 m quadrat. Only one relevè-group (3), exhibits spatial integrity.

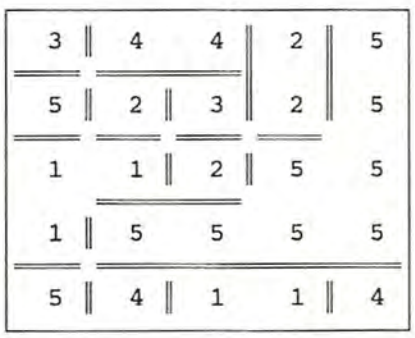



FIGURE 4.5. - Position of 2 x 2 m sampling units in the second 10 x 10 m quadrat showing relevè grouping according to the classification (Table 4.19), by relevè-group numbers in the position of each relevè. Each of the relevè-groups has a common border with the 10 x 10 m quadrat. No relevè-groups exhibit complete spatial integrity.

influence DECORANA results and that noise and pattern are opposites. The argument that ordination can determine discontinuities in vegetation and hence the need for classification (Gauch 1982) is no longer relevant because the PHYTOTAB-PC programs determine such discontinuities as part of the classification process. If no discontinuities are present, only one relevè-group will be obtained. The CANOCO version of DECORANA is preferred because a) greater flexibility is possible with axis comparisons; b) point data is printed on the scattergrams; and c) other ordination options are available such as principal component analysis, reciprocal averaging and canonical correspondence analysis. The last-mentioned option was not tested because vegetation is classified using combined floristics and environmental variables, whereas the aim of this study is to classify purely according to floristics. A combined classification is also likely to be influenced by the selection of environmental variables.

The results of the PHYTOTAB-PC classification of the two 10 x 10 m quadrats are given in Tables 4.18 and 4.19 with diagrams of the sampling unit positions shown in Figures 4.4 and 4.5 respectively. In Table 4.18 all the relevè-groups except the last (relevè-group 5) are characterized by community diagnostic species. Table 4.19 is similar but relevè-group 3, without community diagnostic species, is situated between relevè-groups 2 and 4. It could be argued that relevè-group 3 should be sequenced at the end of the relevè-groups to eliminate the gap in the middle of the matrix. However, this would increase the total separation units to 147 and reduce the classification efficiency to 59%. The reason for this

TABLE 4.20. - PHYTOTAB-PC classification of the combined data sets in the second study area. Total separation units=375. Classification efficiency=68%

| Relevé-group number: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Relevé number: | 02 45 | 121221 009218 | 010011110 618237629 | 02 54 | 4434434 9408346 | 13 58 | 5 0 | 3344 5950 | 04 37 | 33 23 | 0014 7142 | 334 761 | 223222 891763 |
| *Helichrysum rugulosum* | 11 | 1 | | | 1 | | | | | | | | |
| *Lippia scaberrima* | 11 | | | 1 | | | | | | | | | |
| *Convolvulus sagittatus* | | 11 | | | | | | | | | | | |
| *Salvia runcinata* | | | 11 | | 11 | | | | | | | | |
| *Tragus berteronianus* | | | | | 11 | 11 | | | | | | | |
| *Phyllanthus maderaspatensis* | | | | | 1111 | 1 | | 1 | | | | | |
| *Eragrostis pseudosclerantha* | | | 1 | | 111 | | | | | | | | |
| *Verbena brasiliensis* | | 11 | 1 | 1 | | | | | | | | | |
| *Eragrostis capensis* | | | | | | 1111 | | | | | | | |
| *Hibiscus microcarpus* | | | 1 | | 11 | | | | | | | | |
| *Melinis repens* | | | | | 1111 | 11 | | | | | | | |
| *Indigofera zeyheri* | | | | | | | 1111 | | | | | | |
| *Trachypogon spicatus* | | | | | 11 1111 | 1 1 | 1111 | 1 | 11 | 1 | 11 | 11 | |
| *Scabiosa columbaria* | | | | 11 | 11111 | 11 | 111 | 1 | 11 | 1 | 111 | 11 | 1 |
| *Heteropogon contortus* | 22 | 2 11 | 22 | 2 | 2 | 122 | 21 | 11 | 2 | 22 | 32 | 1 | 222 |
| *Eragrostis chloromelas* | 33 | 323332 | 333433233 | 33 | 3323333 | 33 | 3 | 3332 | 33 | 33 | 3423 | 333 | 323333 |
| *Hyparrhenia anamesa* | 33 | 3 3333 | 333433333 | 33 | 3333333 | 33 | 3 | 333 | 33 | 33 | 3333 | 333 | 333333 |
| *Elionurus muticus* | 22 | 22222 | 22222 | 22 | 22 | 2122122 | 22 | 2 | 222 | 22 | 22 | 3121 | 223 | 222232 |
| *Conyza podocephala* | 11 | 11 111 | 111111111 | 11 | 1111111 | 11 | 1 | 1111 | 11 | 1 | 1 | 1 111 | 1 | 1111 |
| *Vernonia oligocephala* | 11 | 11 | 1 | 11 | 1 1 | 111111 | 1 | | 1111 | 1 | 11 | 11 111 | 11111 | |
| *Cymbopogon excavatus* | 23 | 3 | 3 | 23 | 33 | 2 | 322 | 3 | | 22 | 22 | 323 | 331 | 33 |
| *Anthospermum pumilum* | | 11 | 1 1111 | 1 | 1 | 1 | 11 | | 1 | 1 | 1 | 111 | 1 | 1 1 |
| *Crabbea angustifolia* | 11 | | 1 1 | 1 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 111 | 111 1 |
| *Hermannia cf. grandifolia* | 11 | 1 | 1 1 | 1 | 1 | 1 | | 1 | | | 1111 | | | |
| *Tagetes minuta* | | 11 | 11 | 111 | 1 | 1 | 1 | | 11 | | | | | |
| *Tephrosia capensis* | | | 1+ | 11 | 1 | | 1 | | 1 | | 1 1 | | 11 | 1 |
| *Brachiaria serrata* | | | | | 11 | 1 | 1 | | 1 | 1 | 1 | 1 | 111 | |
| *Sutera* sp. | | | | 11 | 11 | | 1 | | 1 | 1 | 1 | 1 | | |
| *Themeda triandra* | | | | | 1 | 1 | 1 | 111 | 1 | 11 | | | | |
| *Chaetacanthus* sp. | | | | | 1 | 1 | | | 1 | | 11 | 1 | 111 | |
| *Aristida congesta* subsp. *barbicollis* | | | 111 | | | 1 | 1 | 111 | | | | | | |
| *Aristida congesta* subsp. *congesta* | | 1 | 21 | | 1 | | | | 1 | | 22 | | | |
| *Helichrysum nudifolium* | | 1 | 1 | | 11 | | | | | | | | | |
| *Verbena tenuisecta* | | | | | | | | | | + | | | | |
| *Athrixia elata* | | | | 1 | | | | | | | | | | |
| *Protasparagus suaveolens* | | | | | | 1 | | | | | | | | |
| *Gazania krebsiana* | | | | | | | | | | | | 1 | | |
| *Dicoma zeyheri* | | | | | | | 1 | | | | | | | |
| *Eragrostis racemosa* | | | | | | | | | | | 1 | | | |
| *Sonchus wilmsii* | | | | | | | | | + | | | | | |

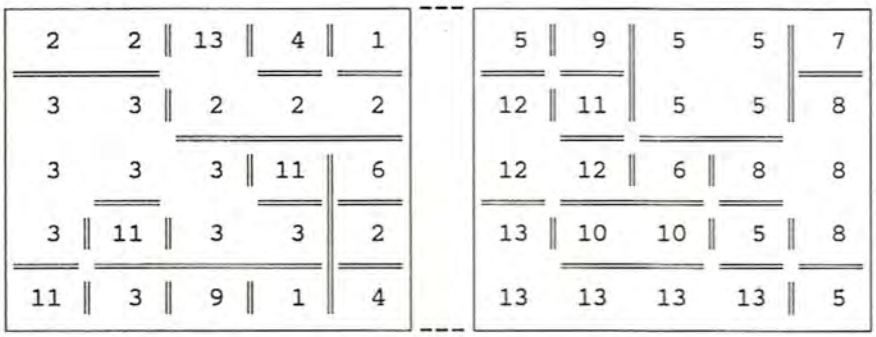



FIGURE 4.6. - Position of 2 x 2 m sampling units in both 10 x 10 m quadrats showing relevè grouping according to the combined classification (Table 4.20), by relevè-group numbers in the position of each relevè. Each of the relevè-groups has a common border with the 10 x 10 m quadrats except for relevès 32 & 33 (relevè-group 10), which are completely included within other relevè-groups. Only three relevè-groups, (6, 9 & 11) comprising relevès: 15, 38; 3, 47; and 7, 1 , 14 & 42, respectively, intersect both data sets.

is the distribution of species such as *Melinis repens*, *Eragrostis capensis*, *Tagetes minuta* and *Helichrysum rugulosum* which, if the relevè-group were moved to the right of the matrix would introduce more gaps than those obtained. This relevè-group is, therefore, regarded as intermediate, floristically, between relevè-groups 2 and 3.

All the relevè-groups have common borders with the 10 x 10 m quadrats. The proportion of the variation of the vegetation units represented by each relevè-group is, therefore, unknown. The unknown proportions, which lie outside the 10 x 10 m quadrats, could obviously be larger in area than the proportions which are represented. Although spatial integrity is restricted to one relevè-group (Figure 4.4), in that all the relevès of that relevè-group have common borders, most of the relevès have common borders with the relevès in each relevè-group. This supports the classifications, especially if the detailed scale is taken into account.

The results of combining the two 10 x 10 m quadrats and producing a single classification are given in Table 4.20. Mean correspondence for the grouped relevè sequences for the separate and combined classifications are 69% for the first quadrat and 35% for the second quadrat. The positions of the classified units are shown in Figure 4.6.

As in Table 4.19, the position of the relevè-groups without community diagnostic species in Table 4.20, are related to species in the non-diagnostic section of the matrix, such as *Hermannia* cf.

*grandifolia*, *Sutera* sp., *Themeda triandra* and *Aristida congesta* subsp. *congesta* which, would increase separation units H and decrease classification efficiency if these relevè-groups were sequenced at the right of the matrix. Based on these species the relevè-groups are regarded as floristically intermediate between the adjacent relevè-groups. This emphasizes the importance of considering all species in a matrix, and not merely the species in the diagnostic section of the matrix, for grouping relevè and sequencing relevè-groups. Furthermore, all species must be considered before a logical grouping into diagnostic and non-diagnostic species can be made. This approach appears to correspond with what occurs in the field where a species is influenced by all the species in its vicinity and not only diagnostic species.

The relevè sequence is of prime importance in classification because this determines relevè-groups, floristic relationships with environment and mapping units. The species sequence is of secondary importance because it only shows species distribution over the determined relevè-groups. Species sequences can, therefore be modified by the user, allowing for more outliers where deemed necessary. In the Tables illustrated in this work, the criterion for species sequences has been minimum outliers, as programmatically sequenced. Relevè-group delimitation, on the other hand, can be changed without affecting the classification efficiency or total separation units i.e relevè-group delimiters can be moved, inserted or removed. However, Van Staden (1992) has shown that moving relevè-group delimiters can affect a community

ordination by reducing the number of SD units obtained. This has the effect of explaining less variation in the data.

Only three relevè-groups intersect both quadrats to form relevè-groups which did not occur in the separate classifications (Figure 4.6). No relevè-group retained its original relevès in the combined classification and only one species-group remained intact in the combined classification. A single vegetation unit, therefore, could be represented by two relevè-groups, each from a different 10 x 10 m quadrat because each relevè-group represents different variation within the vegetation unit, at the scale concerned. Although all plants within the study area were sampled with the contiguous sampling units, this nevertheless, illustrates that the sampling was inadequate in terms of the variation of the vegetation units, included within the study area. In other words, the vegetation units included in the study area are too small to adequately represent the variation of the vegetation units of which each is a part. Hence, the inconsistency in synthesizing the two data sets. It is, therefore, suggested that syntheses can only be reliably done where the vegetation units synthesized are entirely included within the respective study areas. In practical terms this means that vegetation units which are intersected by the borders of a study area can not be reliably synthesized because the proportion of variation included within the study area is unknown. Thus vegetation unit sampling adequacy relates not only to the proportion of species sampled within the study area but also to the degree that the vegetation unit variation is represented within the study area. This should also be considered

TABLE 4.21.- Synoptic version PHYTOTAB-PC. Total separation units=5. Classification efficiency=82%

| Community: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| *Helichrysum rugulosum* | 3 | | | | |
| *Lippia scaberrima* | 2 | + | | | |
| *Convolvulus sagittatus* | 2 | | | | |
| *Scabiosa columbaria* | | 5 | | | |
| *Tephrosia capensis* | | + | 3 | | |
| *Salvia runcinata* | | | 2 | | |
| *Tragus berteronianus* | | | 2 | | |
| *Phyllanthus maderaspatensis* | | + | 2 | | |
| *Aristida congesta* subsp. *barbicollis* | | | 2 | | |
| *Eragrostis pseudosclerantha* | + | | 2 | | |
| *Helichrysum nudifolium* | | | 1 | | |
| *Tagetes minuta* | 2 | | 3 | + | |
| *Chaetacanthus* sp. | | | | 5 | |
| *Aristida congesta* subsp. *congesta* | | | 2 | 4 | |
| *Sutera* sp. | | 5 | 2 | 4 | |
| *Anthospermum pumilum* | 2 | + | 4 | 5 | |
| *Heteropogon contortus* | 3 | 4 | 2 | 4 | |
| *Cymbopogon excavatus* | + | | 3 | 5 | 5 |
| *Eragrostis chloromelas* | 5 | 5 | 5 | 5 | 5 |
| *Hyparrhenia anamesa* | 5 | 5 | 5 | 5 | 5 |
| *Elionurus muticus* | 5 | 5 | 4 | 5 | 5 |
| *Conyza podocephala* | 5 | 5 | 5 | + | 5 |
| *Vernonia oligocephala* | 2 | 4 | 2 | 4 | 5 |
| *Hermannia* cf. *grandifolia* | 2 | + | 2 | 4 | 5 |
| *Crabbea angustifolia* | 2 | | 2 | | |
| *Verbena brasiliensis* | 2 | | 1 | | |
| *Protasparagus suaveolens* | | + | | | |
| *Melinis repens* | | + | | | |
| *Hibiscus microcarpus* | | | + | | |
| *Verbena tenuisecta* | | | | + | |
| *Athrixia elata* | | + | | | |

TABLE 4.22.- Synoptic version of Table 4.19 using PHYTOTAB-PC. Total separation units=4. Classification efficiency=75%

| Community: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| *Chaetacanthus* sp. | 4 | + | + | | |
| *Hermannia* cf. *grandifolia* | | 4 | | | |
| *Hibiscus microcarpus* | | 3 | | | |
| *Helichrysum nudifolium* | | | 3 | | |
| *Phyllanthus maderaspatensis* | | | 3 | | |
| *Aristida congesta* subsp. *barbicollis* | | | | 3 | |
| *Indigofera zeyheri* | | | | 2 | |
| *Sutera* sp. | | | | 1 | |
| *Themeda triandra* | | | 3 | 4 | |
| *Heteropogon contortus* | | 3 | 5 | 3 | 4 |
| *Eragrostis chloromelas* | 5 | 5 | 5 | 5 | 5 |
| *Elionurus muticus* | 5 | 5 | 5 | 5 | 5 |
| *Hyparrhenia anamesa* | 5 | 5 | 5 | 5 | 5 |
| *Conyza podocephala* | 4 | 5 | 5 | 5 | 5 |
| *Trachypogon spicatus* | 3 | 5 | 5 | 4 | 5 |
| *Vernonia oligocephala* | 5 | 3 | 5 | 4 | 5 |
| *Scabiosa columbaria* | 4 | 3 | 5 | 5 | 4 |
| *Crabbea angustifolia* | 5 | 3 | | + | 3 |
| *Cymbopogon excavatus* | 4 | 3 | + | 4 | 2 |
| *Brachiaria serrata* | 2 | 5 | | 3 | 2 |
| *Anthospermum pumilum* | 2 | + | + | | 2 |
| *Tephrosia capensis* | 2 | | + | + | 1 |
| *Melinis repens* | | 3 | + | 3 | |
| *Eragrostis capensis* | | | 5 | + | + |
| *Tagetes minuta* | | + | + | 3 | |
| *Helichrysum rugulosum* | | + | | | |
| *Aristida congesta* subsp. *congesta* | | | | + | |
| *Gazania krebsiana* | + | | | | |
| *Dicoma zeyheri* | | | | | + |
| *Eragrostis racemosa* | | + | | | |
| *Sonchus wilmsii* | | | | + | |

TABLE 4.23.- Re-classification .21 & 4.22 and emphasizing communit
diagnostic species. Total separation units=32. Classification efficiency=76%.
Relevè numbers for Table 4.22 have been renumbered from 6 to 10

| Community number: | 0 5 | 0 4 | 0 6 | 0 8 | 1 0 | 0 9 | 0 3 | 0 7 | 0 2 | 0 1 |
|---|---|---|---|---|---|---|---|---|---|---|
| *Eragrostis capensis* | | | | 5 | + | + | | | | |
| *Indigofera zeyheri* | | | | | 2 | | | | | |
| *Salvia runcinata* | | | | | | | 2 | | | |
| *Tragus berteronianus* | | | | | | | 2 | | | |
| *Eragrostis pseudosclerantha* | | | | | | | 2 | | | + |
| *Hibiscus microcarpus* | | | | | | | + | 3 | | |
| *Helichrysum rugulosum* | | | | | | | | + | | 3 |
| *Lippia scaberrima* | | | | | | | | | + | 2 |
| *Convolvulus sagittatus* | | | | | | | | | | 2 |
| *Eragrostis chloromelas* | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| *Hyparrhenia anamesa* | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| *Elionurus muticus* | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 5 | 5 | 5 |
| *Conyza podocephala* | 5 | + | 4 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| *Vernonia oligocephala* | 5 | 4 | 5 | 5 | 5 | 4 | 2 | 3 | 4 | 2 |
| *Cymbopogon excavatus* | 5 | 5 | 4 | + | 2 | 4 | 3 | 3 | | + |
| *Hermannia* cf. *grandifolia* | 5 | 4 | | | | | 2 | 4 | + | 2 |
| *Anthospermum pumilum* | | 5 | 2 | + | 2 | | 4 | + | + | 2 |
| *Heteropogon contortus* | | 4 | | 5 | 4 | 3 | 2 | 3 | 4 | 3 |
| *Crabbea angustifolia* | | | 5 | | 3 | + | 2 | 3 | | 2 |
| *Scabiosa columbaria* | | | 4 | 5 | 4 | 5 | | 3 | 5 | |
| *Tephrosia capensis* | | | 2 | + | 1 | + | 3 | | + | |
| *Trachypogon spicatus* | | | 3 | 5 | 5 | 4 | | 5 | | |
| *Brachiaria serrata* | | | 2 | | 2 | 3 | | 5 | | |
| *Sutera* sp. | | 4 | | | 1 | | 2 | | 5 | |
| *Tagetes minuta* | | | | + | | 3 | 3 | + | | 2 |
| *Melinis repens* | | | | + | | 3 | | 3 | + | |
| *Aristida congesta* subsp. *congesta* | | 4 | | | | + | 2 | | | |
| *Verbena brasiliensis* | | | | | | | 1 | | | 2 |
| *Chaetacanthus* sp. | | 5 | 4 | + | | | | | | |
| *Themeda triandra* | | | | | 4 | 3 | | | | |
| *Aristida congesta* subsp. *barbicollis* | | | | | 3 | | 2 | | | |
| *Helichrysum nudifolium* | | | | | | 3 | 1 | | | |
| *Phyllanthus maderaspatensis* | | | | | | 3 | 2 | | + | |
| *Verbena tenuisecta* | | + | | | | | | | | |
| *Athrixia elata* | | | | | | | | | + | |
| *Protasparagus suaveolens* | | | | | | | | | + | |
| *Gazania krebsiana* | | | + | | | | | | | |
| *Dicoma zeyheri* | | | | | + | | | | | |
| *Eragrostis racemosa* | | | | | | | | + | | |
| *Sonchus wilmsii* | | | | | | + | | | + | |

when describing vegetation unit variation for a single study area.

The classification results of the two 10 x 10 m contiguously sampled quadrats (Tables 4.18 & 4.19) show that discontinuities can be found in contiguously sampled data and that such data can be classified. Furthermore, high classification efficiencies are obtained with detailed sampling, indicating the effectiveness of the PHYTOTAB-PC programs for large scale work.

Table 4.21 is a synoptic version of Table 4.18; Table 4.22 is a synoptic version of Table 4.19; and Table 4.23 shows the result of combining Tables 4.21 and 4.22 and re-classifying objectively to produce a single classification, using the PHYTOTAB-PC program package. No subjective decisions were made in the re-classification process. In Table 4.23 only community diagnostic species non-diagnostic species have been shown to facilitate comparisons. The community diagnostic species-groups are reduced with the combined classification from a total of eight to five. The only species-group which remains unchanged is the first species-group in Table 4.21 which is the last diagnostic species-group in Table 4.23. The integrity of the original relevè-groups, which formed the synoptic matrices, remains unchanged but the species-groups and the relationships between the relevè-groups has altered considerably. Therefore, re-classification of the separate synoptic tables has not improved the synthesis which confirms that vegetation unit variation sampling was inadequate.

Inadequate vegetation unit variation sampling, as illustrated above, can also explain why division of a data set into subsets, as suggested by Coetzee (1982), to improve classifiability, appears to improve vegetation classifications. It is suggested that division of a data set has the effect of increasing the number of vegetation units by dividing vegetation units at a particular scale into variations of the vegetation units, so that a variation is regarded as a vegetation unit. This can only increase the number of vegetation units by:

$$I = J$$

where I = increase in vegetation units; and

J = number of subsets in which vegetation units occur more than once.

Clearly this can not improve the results because the increase can only be obtained by division of common vegetation units. Although the resulting vegetation units could be regarded as vegetation units at a larger scale they could also be highly arbitrary. This is dependent on the manner in which the original data set is subdivided. However, the reason for subdivision is usually to improve a classification so that it can be assumed that such subdivisions are not based on a verified classification i.e. confirmed floristic relationships, but possibly some or other habitat factor. Such floristic and habitat correlations can only be reliably shown after a classification, so that subdividing a data set to improve a classification can only be considered a doubtful practice. This is confirmed by Van Staden (1992) where the study area could be divided into Arid Bushveld and Mixed Bushveld (Acocks 1975, 1988). However, his koppies which are

TABLE 4.24. - PHYTOTAB-PC random classification (1) of the first data set in the second study area. Total separation units=260. Classification efficiency=40%

| Relevè number: | 00111001 82043417 | 12 81 | 20 37 | 2201 4251 | 210 563 | 200111 069952 |
|---|---|---|---|---|---|---|
| *Eragrostis pseudosclerantha* | 11 1 | 1 | | | | |
| *Aristida congesta* subsp. *barbicollis* | 1 1 1 | | | | | |
| *Chaetacanthus* sp. | 1 1 | | | | 1 | |
| *Convolvulus sagittatus* | | 11 | | | | |
| *Lippia scaberrima* | | | | 11 | | 1 |
| *Scabiosa columbaria* | | | | 1 1 | | 1 |
| *Helichrysum rugulosum* | | 1 | | | 1 | 1 |
| *Sutera* sp. | 1 | | 1 | 1 1 | 1 | 1 11 |
| *Eragrostis chloromelas* | 34323343 | 23 | 33 | 3333 | 323 | 233333 |
| *Hyparrhenia anamesa* | 34333333 | 33 | 33 | 3333 | 333 | 33333 |
| *Conyza podocephala* | 111 11 1 | 11 | 11 | 1111 | 111 | 111 11 |
| *Elionurus muticus* | 2222221 | 2 | 23 | 2222 | 2 2 | 222222 |
| *Anthospermum pumilum* | 11 11 11 | 11 | 1 | 1 | 1 | 1 1 |
| *Vernonia oligocephala* | 1 11 1 1 | | | 1 | 111 | 1 1 1 |
| *Heteropogon contortus* | 22 32 | 2 | 2 | 2 1 | | 21 22 |
| *Cymbopogon excavatus* | 2 3322 | | 3 | | 3 2 | 333 3 |
| *Hermannia* cf. *grandifolia* | 11 11 | 1 | 1 | 1 | 11 | 1 |
| *Tagetes minuta* | 1 1 | 1 | | 1 1 | 11 | 1 |
| *Aristida congesta* subsp. *congesta* | 21 2 | | 2 | | 1 | 1 |
| *Tephrosia capensis* | 1+ | | 1 | 1 | 1 | 1 |
| *Crabbea angustifolia* | 1 1 1 | | | | | 1 1 |
| *Phyllanthus maderaspatensis* | 1 1 | | | 1 | 1 | 1 |
| *Salvia runcinata* | | | | 1 | 1 | 1 1 |
| *Tragus berteronianus* | 1 1 | | | | | 1 1 |
| *Verbena brasiliensis* | 1 1 | | | 1 1 | | |
| *Helichrysum nudifolium* | 1 | | | 1 | | |
| *Protasparagus suaveolens* | | | | | | 1 |
| *Melinis repens* | | | | | | 1 |
| *Hibiscus microcarpus* | 1 | | | | | |
| *Verbena tenuisecta* | + | | | | | |
| *Athrixia elata* | | | | 1 | | |

TABLE 4.25. - PHYTOTAB-PC random classification (2) of the first data set in the second study area. Total separation units=272. Classification efficiency=37%

| Relevè number: | 0211112 5404190 | 1010 3859 | 210 362 | 2 5 | 21 17 | 021 622 | 01000 48173 |
|---|---|---|---|---|---|---|---|
| *Lippia scaberrima* | 1 1 | | | | | 1 | |
| *Scabiosa columbaria* | 11 | 1 | | | | | |
| *Helichrysum rugulosum* | 11 | | | | | | 1 |
| *Crabbea angustifolia* | 1 1 | 11 1 | | | | | |
| *Chaetacanthus* sp. | 1 | | | | | | 1 1 |
| *Aristida congesta* subsp. *congesta* | | 2 | 1 | | 1 | | 221 |
| *Eragrostis chloromelas* | 3332332 | 3333 | 324 | 3 | 33 | 333 | 32433 |
| *Hyparrhenia anamesa* | 333333 | 3333 | 334 | 3 | 33 | 333 | 33333 |
| *Elionurus muticus* | 2222222 | 2222 | 2 2 | 2 | 2 | 222 | 2 132 |
| *Conyza podocephala* | 111 1 1 | 1111 | 111 | 1 | 11 | 111 | 11 11 |
| *Anthospermum pumilum* | 1 1 | 11 | 1 | | 11 | 1 1 | 1111 |
| *Heteropogon contortus* | 2 2122 | 2 2 | 2 | | 2 | 1 | 23 |
| *Cymbopogon excavatus* | 3 3 | 3 3 | 2 | 3 | | 3 3 | 2 232 |
| *Vernonia oligocephala* | 1 11 1 | 111 | 1 | 1 | 1 | | 1 1 |
| *Hermannia cf. grandifolia* | 1 11 | | 1 | 1 | | 1 | 1111 |
| *Sutera* sp. | 11 1 | 11 | | | | 1 | 11 |
| *Tagetes minuta* | 1 | 1 | 1 | | 11 | 11 | 1 |
| *Tephrosia capensis* | 1 | 1 | 1+ | | | 1 | 1 |
| *Phyllanthus maderaspatensis* | 1 | 1 | 1 | | 1 | 1 | |
| *Tragus berteronianus* | | 1 1 | | | 1 | 1 | |
| *Verbena brasiliensis* | 1 | | | | 11 | 1 | |
| *Salvia runcinata* | 1 | | 1 | | | 1 1 | |
| *Eragrostis pseudosclerantha* | | 11 | 1 | | | | 1 |
| *Aristida congesta* subsp. *barbicollis* | | 1 | 1 | | 1 | | |
| *Helichrysum nudifolium* | 1 | | 1 | | | | |
| *Convolvulus sagittatus* | | | | | 1 | | 1 |
| *Protasparagus suaveolens* | | 1 | | | | | |
| *Melinis repens* | | 1 | | | | | |
| *Hibiscus microcarpus* | | | | | 1 | | |
| *Verbena tenuisecta* | | | | | | | + |
| *Athrixia elata* | 1 | | | | | | |

TABLE 4.26. - PHYTOTAB-PC random classification (3) of the first data set in the second study area. Total separation units=263. Classification efficiency=39%

| Relevè number: | 200201 563155 | 101 244 | 112 804 | 2101 2619 | 0 9 | 02012101 23830771 |
|---|---|---|---|---|---|---|
| *Scabiosa columbaria* | 11 | | 1 | | | |
| *Sutera* sp. | 1 11 1 1 | 1 | | 1 | | 1 |
| *Lippia scaberrima* | 1 | | | 1 1 | | |
| *Hermannia* cf. *grandifolia* | 11 1 | 11 | 11 | 11 | | 1 |
| *Eragrostis pseudosclerantha* | | | 1 | | | 1 11 |
| *Aristida congesta* subsp. *barbicollis* | | | | | | 1 1 1 |
| *Helichrysum nudifolium* | | | | | | 1 1 |
| *Crabbea angustifolia* | | | 1 | | 1 | 111 |
| *Eragrostis chloromelas* | 333333 | 332 | 233 | 3243 | 3 | 43332333 |
| *Hyparrhenia anamesa* | 333333 | 333 | 333 | 3333 | 3 | 4333 333 |
| *Elionurus muticus* | 222222 | 222 | 22 | 2 12 | 2 | 22222 32 |
| *Conyza podocephala* | 111111 | 11 | 111 | 11 | 1 | 11111111 |
| *Anthospermum pumilum* | 111 | 1 1 | 1 1 | 1 | | 1 11 11 |
| *Vernonia oligocephala* | 1 1 11 | 11 | 1 | 1 | 1 | 1 11 |
| *Cymbopogon excavatus* | 332 | 323 | | 2 | 3 | 2 33 3 |
| *Heteropogon contortus* | 1 2 | 2 | 2 2 | 32 | | 2 222 1 |
| *Tagetes minuta* | 11 | 1 | | 11 | | 1 1 1 |
| *Tephrosia capensis* | 1 | 1 | | 1 | | + 1 1 |
| *Aristida congesta* subsp. *congesta* | 11 | | | 2 | | 1 2 2 |
| *Phyllanthus maderaspatensis* | | 1 | 1 | 1 | | 1 1 |
| *Tragus berteronianus* | | 1 | | | 1 | 1 1 |
| *Verbena brasiliensis* | 1 | | | 1 | | 1 1 |
| *Salvia runcinata* | 1 | 1 | | 1 | | 1 |
| *Chaetacanthus* sp. | 1 | 1 | | 1 | | |
| *Helichrysum rugulosum* | | | 1 | 1 | | 1 |
| *Convolvulus sagittatus* | 1 | | 1 | | | |
| *Protasparagus suaveolens* | 1 | | | | | |
| *Melinis repens* | 1 | | | | | |
| *Hibiscus microcarpus* | | | | | | 1 |
| *Verbena tenuisecta* | | | | + | | |
| *Athrixia elata* | | | 1 | | | |

TABLE 4.27. - PHYTOTAB-PC random classification (4) of the first data set in the second study area. Total separation units=296. Classification efficiency=32%

| Relevè number: | 11110202 24396430 | 12120120 75837019 | 00 28 | 21 21 | 01 46 | 100 551 |
|---|---|---|---|---|---|---|
| *Chaetacanthus* sp. | 1 1 | | | | | 1 |
| *Helichrysum rugulosum* | 1 1 | 1 | | | | |
| *Convolvulus sagittatus* | | 1 1 | | | | |
| *Cymbopogon excavatus* | 333 3 23 | 3 3 3 | 2 | | 2 | 2 |
| *Crabbea angustifolia* | 1 1 | 1 1 1 | 1 | | | |
| *Tragus berteronianus* | 1 1 | 1 1 | | | | |
| *Phyllanthus maderaspatensis* | 1 1 1 | 1 | | | 1 | |
| *Anthospermum pumilum* | 111 111 | 1 1 1 1 | 11 | | | 1 |
| *Scabiosa columbaria* | 1 | | | | | 11 |
| *Eragrostis chloromelas* | 32333332 | 33233333 | 43 | 33 | 32 | 334 |
| *Hyparrhenia anamesa* | 3333333 | 33333333 | 43 | 33 | 33 | 333 |
| *Elionurus muticus* | 22222222 | 2 23222 | 22 | 22 | 2 | 221 |
| *Conyza podocephala* | 1 1 1111 | 11111111 | 11 | 11 | 11 | 11 |
| *Heteropogon contortus* | 22212 2 | 2 22 | | 1 | | 2 3 |
| *Vernonia oligocephala* | 1 11 | 11 1 1 | 1 | | 11 | 11 |
| *Hermannia* cf. *grandifolia* | 1 1 | 11 11 | | | 11 | 11 |
| *Tagetes minuta* | 1 1 | 1 1 | 1 | 11 | 1 | |
| *Sutera* sp. | 11 11 | 1 1 | | | | 11 |
| *Aristida congesta* subsp. *congesta* | 1 1 | 2 | 12 | | | 2 |
| *Tephrosia capensis* | 1 | 1 | +1 | | 1 | 1 |
| *Verbena brasiliensis* | 1 | 1 | | 11 | | |
| *Eragrostis pseudosclerantha* | 1 | 1 | 11 | | | |
| *Salvia runcinata* | 1 1 | | | 1 | 1 | |
| *Lippia scaberrima* | 1 | | | 1 | | 1 |
| *Aristida congesta* subsp. *barbicollis* | 1 | 1 | 1 | | | |
| *Helichrysum nudifolium* | | | 1 | 1 | | |
| *Protasparagus suaveolens* | | | | | | 1 |
| *Melinis repens* | | | | | | 1 |
| *Hibiscus microcarpus* | | 1 | | | | |
| *Verbena tenuisecta* | | | | | | + |
| *Athrixia elata* | 1 | | | | | |

geographically and floristically part of the Mixed Bushveld would be separated from the footslopes which floristically are part of the Arid Bushveld.

In Tables 4.24 to 4.27 the relevè sequences have been generated with a random number generator available on the PHYTOTAB-PC package. The data is the same as that for Table 4.18. Relevè-groups have been formed and species sequenced programmatically. Pattern is evident in all four Tables and classification efficiencies are 40% or less. The number of diagnostic species is not necessarily correlated with the classification efficiency, because Table 4.27 has 32% classification efficiency and nine diagnostic species, whereas, Table 4.25 has 37% classification efficiency and only six diagnostic species. These Tables indicate that a classification efficiency of 40% or less is comparable to that which can be obtained with a random relevè sequence and that not much credence should be given to such classifications.

These results are only four of many tested to show that a classification is not unique and that many arbitrary solutions are possible, so that virtually any relevè sequence could produce some sort of pattern. The presence of noise in the form of outliers or gaps in a species distribution over the relevè sequence preclude the attainment of 100% classification efficiency.

What then is an adequate classification? It appears from the results that classification efficiencies of 60% or higher can be considered adequate, but the user will not know if, for example,

65% is the best obtainable or if through further sequencing a better classification can be obtained. In all the tests conducted, no higher classification efficiency was obtained than that obtained with the PHYTOTAB-PC programs. It must be remembered that the classification efficiency relates to relevè sequence and not relevè-group delimitation or species sequence, both of which can change without affecting the classification efficiency value. These changes could, however, effect pattern in terms of species sequencing.

The relevè sequence determines which relevès can be grouped to form relevè-groups and also the relationships between relevè-groups. The delimitation of relevè-groups according to a given relevè sequence is influenced by the scale at which relevè-groups are to be recognized. If the species are not sequenced, no pattern will be evident at this stage, but neither the relevè-group delimitation nor the relationships between relevè-groups will be affected and the classification efficiency value will remain the same. The advantage of this approach to classification, is that with correct species sequencing the adequacy of a classification can be inferred, to an extent, by pattern strength through relevè-group delimitation and species sequencing. The PHYTOTAB-PC programs, sequence species according to minimum noise. The user can increase pattern strength through selective re-sequencing of species. This is, however, based on subjective decisions as to what is an adequate balance between noise and pattern.

Gauch (1982) regards noise (unco-ordinated occurrences) and

pattern (co-ordinated occurrences) as opposites, in that if noise is decreased then pattern is increased. He further regards noise as unquantifiable. As has been shown, pattern is unquantifiable. Noise, however, can be attributed to three sources, namely, i) that which is related to a relevè sequence and can be quantified in terms of included blanks; ii) that which is related to a species sequence and relates mainly to outliers; and iii) that which is related to relevè-group delimitation and also can relate to outliers. The first-mentioned can be quantified in terms of separation units which determine the relevè sequence that produces least noise overall, for a given data set. This should also be the sequence in which pattern, after relevè-group delimitation and species sequencing, is strongest. This supports hypothesis (iv) in Section 1.3. However, species sequence-related noise, is not quantifiable because of differences in the amount that could be permitted by different users for a particular data set. The flexibility, in species sequencing is an advantage because it permits matrix simplification, in terms of grouping species groups to form gradients, without loss of information, as suggested in Section 3.5.2.1. The last-mentioned source of noise is relevè-group delimitation which is essentially related to scale and can affect species sequencing, as has been shown. The use of noise to obtain a relevè sequence and hence classify the vegetation can be described as a minimum entropy method.

The relevè-group delimitation programs allow for some flexibility in relevè-group delimitation so that the classification can match the scale of the stratification, but all the relevè-groups are de-

TABLE 4.28. - Commonality index of relevès with species occurrences in relevès and relevè-groups represented, from PHYTOTAB-PC, for the first data set, in the second study area

| Relevè number | Commonality Index | Species occurrences | Relevè-group |
|---|---|---|---|
| 23 | 125 | 5 | 1 |
| 19 | 175 | 7 | 1 |
| 10 | 175 | 7 | 1 |
| 22 | 200 | 8 | 1 |
| 4 | 200 | 8 | 5 |
| 25 | 200 | 8 | 5 |
| 20 | 200 | 8 | 1 |
| 11 | 225 | 9 | 3 |
| 18 | 225 | 9 | 1 |
| 9 | 225 | 9 | 3 |
| 21 | 225 | 9 | 1 |
| 16 | 250 | 10 | 3 |
| 1 | 250 | 10 | 4 |
| 6 | 275 | 11 | 3 |
| 7 | 275 | 11 | 3 |
| 14 | 275 | 11 | 4 |
| 15 | 275 | 11 | 2 |
| 24 | 275 | 11 | 2 |
| 8 | 275 | 11 | 3 |
| 3 | 275 | 11 | 4 |
| 12 | 300 | 12 | 3 |
| 17 | 300 | 12 | 3 |
| 13 | 300 | 12 | 3 |
| 2 | 300 | 12 | 3 |
| 5 | 300 | 12 | 2 |

limited at the same scale. Where mixed scales are present, the user can adjust relevè-group delimitation by inserting or removing relevè-group delimiters.

Objectivity in a classification is inversely proportional to the number of decisions required to complete the classification. It is for this reason that stratification and sampling should be according to scale so that fewer decisions are required in the classification process, thereby increasing objectivity.

Although field proficiency can increase with repetition the complexity and processing time increase exponentially with data set size. Furthermore, redundancy also appears to increase with data set size. It is, therefore, suggested that for maximum efficiency, data sets should not exceed 150 relevès, where possible. Automatic relevè sequencing with the PHYTOTAB-PC program package is also limited to a product of species and relevès of 186 000 which limits species to 1240 for 150 relevès. The other programs in the package do not have such limitations and are dependent on hard disk space.

Table 4.28 gives the commonality sequence output for relevès, using the PHYTOTAB-PC program package, together with relevè-group numbers in which each relevè occurs. The first seven relevès occur in either of the extreme relevè-groups, whereas the last 14 occur in the central relevè-groups. It is the identification of the extreme relevès that facilitate the heuristic approach to relevè sequencing. Outliers can confuse this pattern in that an extreme

TABLE 4.29. - Commonality index of species with species occurrences and position in the classified matrix, from PHYTOTAB-PC for the first data set in the second study area

| Species | Commonality Index | Species occurrences | Position in matrix |
|---|---|---|---|
| *Verbena tenuisecta* | 10 | 1 | |
| *Protasparagus suaveolens* | 11 | 1 | single |
| *Melinis repens* | 11 | 1 | occurrences |
| *Athrixia elata* | 11 | 1 | |
| *Hibiscus microcarpus* | 12 | 1 | |
| *Convolvulus sagittatus* | 18 | 2 | |
| *Helichrysum nudifolium* | 21 | 2 | |
| *Helichrysum rugulosum* | 24 | 3 | |
| *Lippia scaberrima* | 27 | 3 | |
| *Chaetacanthus* sp. | 32 | 3 | mainly |
| *Scabiosa columbaria* | 34 | 3 | diagnostic |
| *Aristida congesta* subsp. *barbicollis* | 36 | 3 | species |
| *Verbena brasiliensis* | 38 | 4 | |
| *Salvia runcinata* | 42 | 4 | |
| *Eragrostis pseudosclerantha* | 44 | 4 | |
| *Tragus berteronianus* | 45 | 4 | |
| *Crabbea angustifolia* | 47 | 5 | |
| *Phyllanthus maderaspatensis* | 57 | 5 | |
| *Aristida congesta* subsp. *congesta* | 66 | 6 | |
| *Tephrosia capensis* | 68 | 6 | |
| *Tagetes minuta* | 82 | 8 | |
| *Sutera* sp. | 88 | 8 | |
| *Hermannia* cf. *grandifolia* | 97 | 10 | |
| *Heteropogon contortus* | 116 | 12 | |
| *Vernonia oligocephala* | 118 | 12 | |
| *Cymbopogon excavatus* | 123 | 12 | |
| *Anthospermum pumilum* | 142 | 13 | |
| *Elionurus muticus* | 213 | 22 | |
| *Conyza podocephala* | 216 | 22 | general |
| *Hyparrhenia anamesa* | 236 | 24 | occurrences |
| *Eragrostis chloromelas* | 244 | 25 | |

TABLE 4.30. - Similarity co-efficients, using the PHYTOTAB-PC program package, for the relevès in the first quadrat, in the second study area

| Relevè number | Similarity co-efficient |
|---|---|
| 23 | 0,000 |
| 11 | 77,778 |
| 22 | 77,273 |
| 21 | 85,000 |
| 6 | 71,429 |
| 7 | 84,615 |
| 2 | 82,143 |
| 8 | 76,667 |
| 3 | 78,571 |
| 14 | 78,571 |
| 1 | 80,769 |
| 25 | 69,231 |
| 4 | 100,000 |
| 10 | 83,333 |
| 9 | 80,000 |
| 20 | 77,273 |
| 13 | 71,429 |
| 17 | 75,000 |
| 12 | 70,588 |
| 16 | 73,333 |
| 5 | 73,333 |
| 15 | 76,667 |
| 24 | 78,571 |
| 19 | 69,231 |

relevè, with a species outlier from a central relevè-group, could cause that relevè to occupy a central position. The exact relevè, however, is not required as only an approximation of the starting relevè is needed to save processing time.

Table 4.29 gives the commonality sequence output for species, using the PHYTOTAB-PC program package, together with the position in the classified matrix that the species occupy. This sequence is not required for species classification but is included for completeness of processing and could be of benefit to users.

No pattern is formed in the classified matrix with single and general occurrence species and these are, therefore, not regarded as diagnostic. Not all the species in the middle group (Table 4.29), are necessarily diagnostic, as their distribution included in the relevant study area, could be inadequate.

Table 4.30 gives the initial similarity co-efficients for each successive pair of relevès. The starting relevè (23) is that obtained from the commonality sequence (Table 4.28). Only two relevès are identical, namely, numbers 25 & 4 (100% similarity). Similarity sequencing, unlike the commonality sequencing, is repeated for a data set and is included to save processing time in relevè-group construction.

Classification efficiencies for some published classifications are as follows: Van Staden (1992) 60%; Scheepers (1975)

Kroonstad 48%; Bethlehem 44%; Leistner (1967) 62% and Westfall *et al.* (1985) 64%.

The classification efficiency of 60% obtained by Van Staden (1992) is considered good because of the integrity of the vegetation units; correspondence between stratification and vegetation units; and correspondence between environment and vegetation units. These results were achieved in an area with weak environmental gradients and no visibly distinct vegetation unit borders. The classification efficiency of 62% obtained by Leistner (1969) is attributed to a low species richness and clearly visible differences in the floristic composition of the vegetation units. This facilitates visual sequencing of relevès and species. Scheepers (1975) worked in generally overgrazed grassland with a high species richness and generally weak environmental gradients. The difficulty experienced in classifying such data sets is shown in the classification efficiencies of 48% (Kroonstad) and 44% (Bethlehem). These results support classification efficiency values as a reliable method of assessing the efficiency of a classification.

The last-mentioned data set (Westfall *et al.* 1985) was reclassified using the PHYTOTAB-PC program package. Relevè-group delimiters were inserted in three relevè-groups in which obvious subdivisions were possible and removed between relevè-groups which had no community diagnostic species. Removal and insertion of delimiters was necessary because the original stratification, and

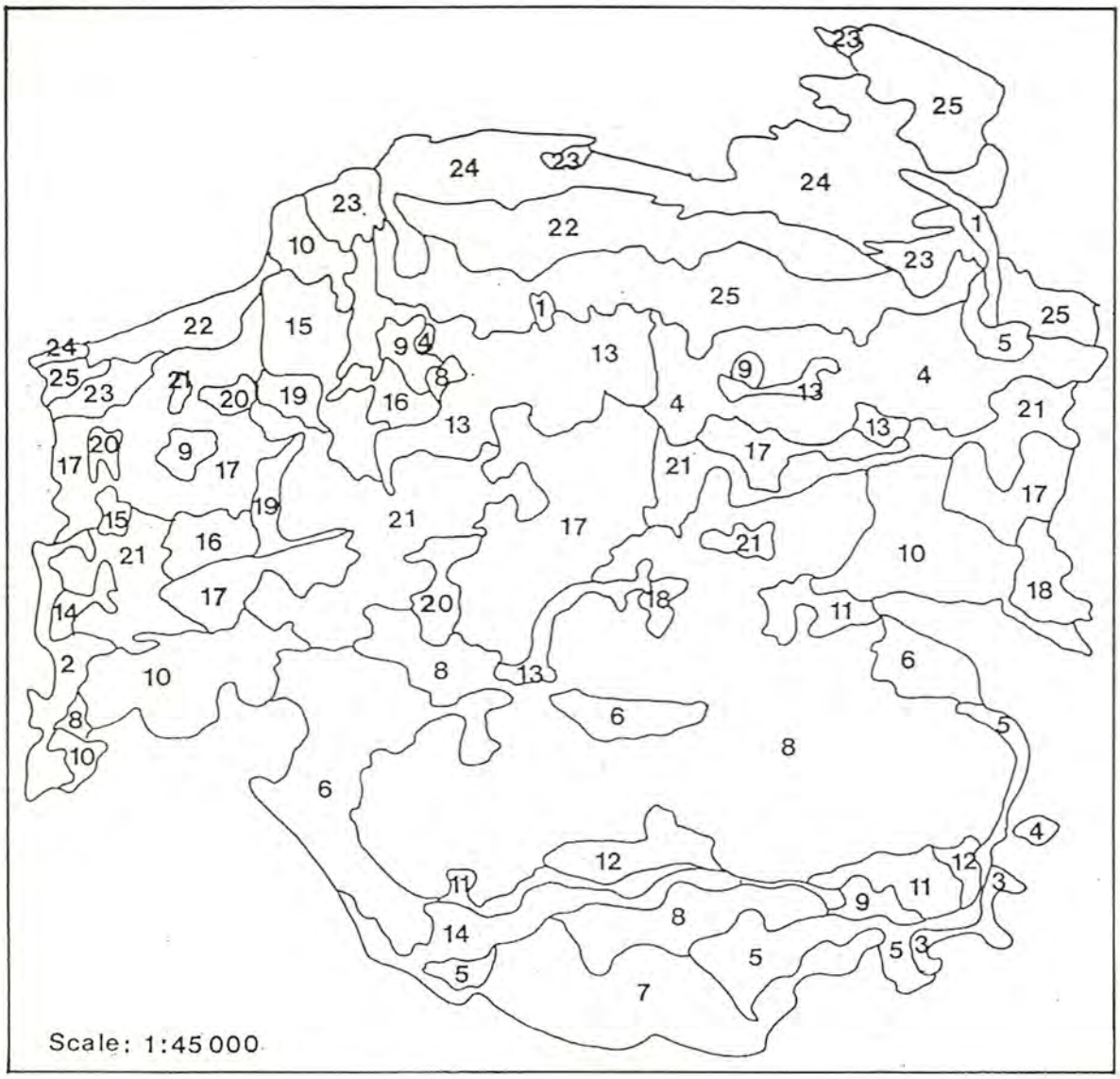



FIGURE 4.7. - The spatial relationships of relevé-groups formed by the re-classification of relevés in Table 4.31. Figures refer to the relevé-group numbers used in the re-classification.

hence sampling, was not according to scale. The results of the re-classification, without altering the programmatic relevè and species sequences, are shown in Table 4.31 (back pocket). Classification efficiency is increased from 64% to 68% and 25 communities can be identified in contrast to the 22 of the original classification (Table 4.32 back pocket). The number of species represented in community diagnostic species-groups is 65 in both classifications, but the re-classification is based on minimum outliers, so that community diagnostic pattern could be enhanced by inclusion of more species with outliers.

Figure 4.7 shows the spatial relationships of the re-classified relevè-groups (Table 4.31). Relevè-groups 1 and 3 are the same for both classifications (Tables 4.31 & 4.32) but in the re-classification their positions are switched thereby making forest associated with North-Eastern Mountain Sourveld the most extreme group on the left of Table 4.31. Relevè-group 3 is then better associated geographically and floristically with Sour Bushveld than in Table 4.32. The extreme relevè-group on the right of Table 4.31 represents North-Eastern Mountain Sourveld as was the case in the original classification. The differences in the classifications are illustrated by a grouped number sequence comparison where the mean correspondence is 36%. This shows a poor comparison between relevè-groups of the two classifications. Generally, the re-classified relevè-groups appear to correspond better with the environment than the original classification. Furthermore, the spatial integrity of the re-classified relevè-groups was such that a much better correspondence was obtained with vegetation pattern

on the aerial photograph, used to show spatial relationships between the re-classified relevè-groups (Figure 4.7), than was obtained with the original vegetation map.

As with Tables 4.19 and 4.20 relevè-groups without community diagnostic species, are regarded as floristically intermediate to the adjacent relevè-groups. Relevè-groups, such as 5 and 8 with a low constancy of community diagnostic species, could probably be improved by including more species in their respective species-groups, although more outliers would be included. Such refinement of the matrix was not the purpose of the classification, however, but rather to show the basic pattern obtainable from the program.

A classification is not necessarily invalid if community diagnostic species have a low constancy. This can be as a result of widely spaced species for which the dimensions of the sampling units (quadrats) are inadequate. To ensure adequate sampling unit dimensions, for community diagnostic species, would require a classification, prior to sampling, to determine which species are diagnostic for communities and suitable sampling unit dimensions for their sampling.

The absence of a community diagnostic species in a particular relevè can be regarded as relevè-related noise and its presence can be inferred by the other species present in the relevè. This is fundamental to the Braun-Blanquet approach (Mueller-Dombois & Ellenberg 1974). The sequencing of species and relevès based on visual pattern formation, however, can be greatly facilitated by

recognition of relevè-groups, in which community diagnostic species have a high constancy. However, this should not preclude the inclusion of relevès in such groups, where the community diagnostic species are absent, if the total floristic composition of the relevès indicates inclusion. It is, therefore, suggested that "total floristics" refers not to sampling, which is clearly not the case (section 3.2.4) but rather to the classification in which all species present in the matrix must be considered.

It is for these reasons that the PHYTOTAB-PC classification (Table 4.31) is considered a better classification than the original visual classification (Table 4.32). The re-classification also supports the hypothesis (iii) that more than one solution is possible in a vegetation data set. However, the problem of what is the "best" classification, still occurs, hence the need for verification.

## 4.4 *VERIFICATION*

The results for this section are shown in Van Staden (1992) as fieldwork is ongoing in the main study area.

Apart from the classification efficiency values and pattern strength, the relationships between the classified vegetation units and stratification units and differentiating environmental factors, are the main criteria in assessing the adequacy of a classification. Such relationships can also have the practical value of improving vegetation map quality as well as the under-

standing of vegetation and hence management implications, in terms of limiting environmental factors.

It is probable that each species distribution, in a study area, could be linked to one or other environmental influence. Classification has the effect of averaging such influences, on a vegetation unit basis, so that the main environmental influences are apparent. It is, therefore, necessary to group the correct species, on a relevè-group basis to show such influences, hence, environmental correlation supporting a classification. The following guidelines are suggested for assessing a classification:

i. scale should be appropriate, for example, seasonality can not be expected to be differentiating at 1:50 000 scale as it is usually applicable at biome scale;
ii. gradients should be present. It is unlikely that a different environmental factor will differentiate each vegetation unit in a study area;
iii. environmental relationships should be relatively simple, because of the averaging effect. Greater complexity could be expected with individual species distributions; and,
iv. environmental relationships should be logical in context. In other words the relationships should make sense for the particular study area.

Furthermore, the use of the PHYTOTAB-PC program package for determining the classification and environmental factor correspondence emphasized the following:

i. environmental relationships are often hierarchical;
ii. class intervals for grouping environmental continua are not

TABLE 4.33. - Alphabetical listing of species selected from the PHYTOBAS data bank from undisturbed dune crests with low rainfall (less than 250 mm) from Leistner (1967)

| | |
|---|---|
| *Acacia erioloba* | *Jatropha erythropoda* |
| *Acacia haematoxylon* | *Lapeirousia littoralis* |
| *Acrotome inflata* | *Limeum arenicolum* |
| *Aristida meridionalis* | *Limeum fenestratum* |
| *Boscia albitrunca* | *Limeum sulcatum* |
| *Brachiaria glomerata* | *Oxygonum delagoense* |
| *Bulbostylis hispidula* | *Phyllanthus omahekensis* |
| *Centropodia glauca* | *Plexipus pumilus* |
| *Chamaesyce inaequilatera* | *Plinthus sericeus* |
| *Citrullus lanatus* | *Pollichia campestris* |
| *Crotalaria spartioides* | *Requienia sphaerosperma* |
| *Cynanchum orangeanum* | *Sesamum* sp. |
| *Eragrostis lehmanniana* | *Stipagrostis amabilis* |
| *Heliotropium ciliatum* | *Stipagrostis uniplumis* |
| *Hermannia tomentosa* | |

necessarily equal; and,

iii. vegetation unit limits need not necessarily correspond with changes in environmental factor values at the same points.

Classification adequacy can also be assessed by the integrity of the vegetation units to be mapped. These should form mappable units, except where outliers occur. The occurrence of outliers can often be attributed to mixed scales such as in Figure 4.7. Ground truth after a classification is not to assess the classification but to assess the reliability of mapped borders as well as the relevancy of community diagnostic species as indicators for the entire communities they represent.

An adequate classification is of little value, however, if its relevancy is low. The relevancy of a classification is directly proportional to the uses that can be derived from it.

## 4.5 *DERIVATIVES*

Community structure, community composition analyses, stand analyses, growth form analyses, community cover assessments, and species cover relationships are programmatically derived using the PHYTOTAB-PC program package and are illustrated by Van Staden (1992). These derivatives increase the understanding of vegetation component interactions and the uses for a classification, considerably. No similar programs are available.

An example of the data bank derivatives is given in Table 4.33 in

which species occurring on dune crests with less than 250 mm mean annual rainfall, are listed. In this case relevè numbers with the required habitat are input. It is necessary to know which relevès are required as the data bank only contains floristic information. A GIS could also be used to select relevès where relevant environmental data sets (coverages) are available.

Where species presence over more than one vegetation unit is required, then species representing all the relevant vegetation units can be selected to retrieve associated species from the data bank using Boolean "and" logic. This could, for example, be applied to determine common species for a stand so that only those not listed, need be recorded in the field. The PHYTOBAS data bank can also be used for a single data set.

A static perspective of vegetation units, which are inherently dynamic, can limit the application potential of vegetation ecology. The dynamic succession approach suggested by Clements (1916) and Bews (1916) appear to confuse scale both spatially and temporally so that the concepts used have little practical relevance. Inferring dynamics of vegetation units from sampling units, representing a moment in time requires that:

i the vegetation units be comparable i.e. sampled at the same scale;

ii. the condition of the vegetation units relative to some reference be known; and,

iii. the trend or direction of change can be inferred, for

TABLE 4.33. - PHYTOTAB-PC applications excluding data input, transfer, corrections and file listing

| | | |
|---|---|---|
| **A** | **Sequencing** | |
| | Automatic relevè sequence | Random sequence |
| | Automatic species sequence | Reverse sequence |
| | Alphanumeric sequence | User sequence |
| | Ascending sequence | |
| **B** | **Classification processing** | |
| | Checklist compilation | Species cover relationships |
| | Community composition analysis | Stand phase analysis |
| | Community cover assessment | Synoptic matrix |
| | Community & habitat correlation | |
| **C** | **Internal utilities** | |
| | Co-ordinate processing | Number set comparisons |
| | Digital mapping | Plant identification key |
| | File merging | Sample & stand dimensions |
| | Format conversion | Statistics |
| **D** | **External utilities** | |
| | 3-D ordination plotting | |
| | Species name search, checking and author additions | |
| **E** | **Data bank** | |
| | Data set splitting | Information retrieval |
| | Data sets synthesis | Species spelling checker |

practical relevance.

The bench mark concept or reference is essential if trend is to be inferred. However, fixed benchmarks, as suggested by Foran *et al.* (1978) can result in such scale and succession differences to the vegetation units for which they serve as reference, that their validity could be questioned. The required number of such benchmarks for relevant-scale work would also be prohibitive. It appears far more feasible for benchmarks to be constructed from relevès representing a particular vegetation unit. Such a benchmark could be: a synoptic relevè; relevès representing the central part of a vegetation unit; or a synthetic relevè based on species composition from the relevès representing the vegetation unit, such as is used with the community composition analysis. Trend can be inferred from a species composition gradient, of relevès representing the vegetation unit, relative to the benchmark. Thus succession appropriate to scale and practical time-span can be determined as is shown with the stand phase analysis. It is, therefore, suggested that veld condition assessment techniques, including vegetation monitoring, for whatever purposes, can only be effective for large areas, if based on an adequate classification.

## 4.6 *PHYTOTAB-PC*

The applications possible with the PHYTOTAB-PC program package are summarized in Table 4.33. The package includes online manuals as well as online fault-finding. Processing speed is dependent on

matrix size. Automatic relevè sequencing is the most time-consuming of the programs and is dependent on matrix size and processor speed. For example, the programs have been tested on an 80486 processor which can halve processing time.

The PHYTOTAB-PC program package is essentially a research tool which can facilitate objectivity in vegetation analyses. The addition of programs to test various results such as comparison of grouped number sequences and the statistical utility program are for research purposes. If a purely production package were required a far simpler package could be developed. Several of the options are unique, such as automatic relevè sequencing, automatic species sequencing, environmental factor correspondence, vegetation component analysis, stand phase analysis and plant identification key generation. These coupled with data bank facilities ensure a powerful and comprehensive tool for vegetation analyses.

The amount of data collected during fieldwork in a typical project is vast. For example, 150 relevès with a total of 400 species represents a matrix of 60 000 cells. To this must be added cover, growth form, and environmental information. Reduction of this information to meaningful pattern requires considerable processing. This is achieved with the PHYTOTAB-PC program package and flexibility in application is still maintained. Data integrity and security is assured by writing all relevant files to separate diskettes. However, a package of this nature with the flexibility offered, presupposes a fundamental knowledge of vegetation classification theory. Without this background a researcher is unlikely

to be able to apply the programs effectively even though they are menu driven and a comprehensive online manual is available.

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**Scale**

The tendency for vegetation heterogeneity to increase with decreasing scale necessitates increasing cognizance of scale, as scale decreases. This is particularly important for: vegetation unit recognition and hence mapping; determining the influence of environment on vegetation units; and vegetation sampling requirements at small-scale. At large-scale, however, where sampling unit dimensions are such that the sampling unit is implicitly representative of a stand, then cognizance of scale can often be implicit. Implicit scale recognition is from about 1:8 000 to about 1:50 000 based on a 200 $m^2$ sampling unit or quadrat. For larger scales a smaller sampling unit would be required. For uniformity, however, and to facilitate communication, it is recommended that scales in vegetation ecology work be explicit.

**Stand area**

Definition of stand area is the means by which scale is made explicit for vegetation sampling in this work. The stand is integral to the Braun-Blanquet method but relies on researcher decisions in its implementation. By linking scale to stand area these decisions are reduced and the stand becomes easier to delimit in the field. It is, therefore, recommended that stand area be linked to scale, as a simple means of expressing scale, in vegetation ecology work.

Although not tested it is hypothesized that the scale-defined

stand can also relate to the minimum sustainable area for the conservation of a vegetation unit.

**Reconnaissance**

This work confirms the necessity of a reconnaissance, prior to sampling, as recommended in the Braun-Blanquet method. However, actions during a reconnaissance are made more explicit for vegetation stratification, by means of both satellite imagery and aerial photography, to determine vegetation variation and produce a preliminary vegetation map. Other actions recommended during reconnaissance are less critical and will depend to a large extent on particular methods adopted.

Although it is possible to obtain the basic data associated with a reconnaissance from an analysis of aerial photographs a comparison of field reconnaissance with aerial photograph analysis was not made.

**Stratification**

This work suggests that, apart from stratifying vegetation for stratified random sampling purposes, a vegetation stratification can be used for a preliminary vegetation map which can also serve as a hypothesis, to be tested by the classification.

Suggested procedures for the use of satellite imagery for small-scale stratification and, although not tested, the potential of larger-scale satellite imagery, for large-scale stratification, are detailed. Application of these computerized procedures for

vegetation stratification has lead to the following suggestions for simplifying the visual use of aerial photography for small scale stratification:

i. that vegetation be primarily stratified according to vegetation structure and cover as perceived by textural and contextual vegetation pattern;

ii. that secondary and further divisions of the primary units be on the basis of topography and other physical factors; and,

iii. that scale can be taken into account by minimum area comparisons.

The use of aerial photography in this way is a visual pattern analysis of aerial photographs rather than the aerial photograph interpretation method whereby topography forms the primary stratification. Thus a stratification of vegetation will be vegetation-based rather than topography-based. Vegetation pattern analysis can also make stereoscopy redundant for small-scale work. These methods have not been adequately tested but preliminary results of a single farm stratified in this way, appear satisfactory.

**Stand location**

Computerized random number generation for a 4 mm grid map overlay, together with grid co-ordinate conversion to degrees, minutes and seconds, reduces decision-making and facilitates objective stand location considerably, for random sampling. Subjective stand location, as can also be applied in the Braun-Blanquet method, is not considered here because of the experience required, which could increase considerably with decreasing scale, in its application.

Precision in stand location requirements will increase in direct proportion to the reliance placed, in the future, on geographic information systems for environmental data. Precision in stand location will also be required when vegetation data is input to geographic information systems. Visual stand location, in this study, proved adequate for classification purposes. However, indirect methods of obtaining environmental data, necessitated greater precision in stand location. Altimeters and optical rangefinders proved inadequate for the precision required. Trigonometrical techniques were not tried because of the cost of apparatus, time required and the inability to detect three beacons at many stands.

Geographic positioning by satellite is recommended for precise stand location and, although not tested, shows potential for saving time where random stand location is applied. Precise location of stands has a further advantage of enhancing the value of sampling data as such data can be used for monitoring purposes.

**Sampling unit area**

The method of sub-sampling a vegetation stand, applied in this study, is not recommended because: a) sub-sampling is time-consuming; b) the methods applied are based on minimum area which can lead to a low degree of constancy in a classified matrix; and c) sub-quadrat sampling has to change from the criterion of rooted plants, in the case of the smaller growth forms, to overhanging plants, for the larger growth forms. It is not certain that, even with the change in criteria, an adequate sample of the larger

growth forms is obtained.

However, the use of a defined stand, as recommended, introduces flexibility into sampling options. Stands can be sampled with a representative quadrat of suitable size, as is often the case, but the limits of representation will be known; large stands can be sub-sampled using quadrats, as applied in this study, but the area of such quadrats may have to be enlarged; point methods can be used within the stand area; and informal sampling using, for example, the plant number scale with pre-determined lower limits, can be applied. The stand defines the limits for the application of these methods, which should enhance repeatability, and hence scientific validity.

The use of the species-area regression can be used for areas up to one hectare, for comparative purposes. Although the regression seems adequate for these purposes, it could probably be improved with more data.

**Sampling unit location**

Sampling units, within the defined stand, which is circular, can be located with vectors, the components of which are direction and distance, from the stand centre, unless the sampling unit area approximates that of the stand, in which case the sampling unit location will be that of the stand. Where sampling is by a plot-less method such as a point method or informal sampling, then the criteria for sampling location should be made known to ensure repeatability. In the case of very large stands i.e. sampling at

very small scales such as 1:500 000 or less then geographic positioning by satellite can be employed. The importance of recording sampling unit location is firstly, to ensure, repeatability for scientific validity, and secondly, to enhance the value of the data so that the data can be used for benchmarks, monitoring and other purposes.

**Plant identification and verification**

The methods applied in this work have improved the species knowledge of the researchers concerned and permitted detection of infra-specific differences in plants, which might otherwise have gone undetected. Apart from the advantage of plant knowledge gained on a systematic basis, it is postulated that making known the criteria by which plants are identified can only improve the scientific validity of vegetation ecology. In the International Metric System (SI) standards have been determined for physical observations. No similar standards exist for botanical observations. Voucher specimens serve as a reference and not as a standard. Furthermore, character and character states used for plant identification in southern Africa vary depending on the systems used, hence, the criteria by which plants are identified should be made known. Without this information, the degree to which vegetation ecology work could be repeated, is very uncertain. The recommendation regarding plant identification is, therefore, aimed at the criteria for identification and not necessarily the methods applied in this study.

**Species cover**

Species canopy cover, which is used in the Braun-Blanquet method, is preferred to basal cover estimations because more information can be derived from the former. Selection of cover class scale is dependent on the aim of a study. A simple, minimum class scale, such as the Braun-Blanquet scale, is likely to produce better cover pattern in a classified matrix, than a scale with many classes. The plant number scale, on the other hand, is preferred where cover values are treated arithmetically, and greater precision is required of cover values, than can be obtained with visual estimation techniques. No advantage can be found for scales with an intermediate number of cover classes, such as the Domin-Krajina cover-abundance scale.

An alternative method of cover determination is that which can be obtained with a point method, such as the wheel-point method. However, care should be exercised because such methods often rely on linear proportionate cover which should be converted to area cover.

**Floristic data recording**

The recommended minimum floristic data to be recorded at each sampling unit are: species presence; canopy cover for each species; and growth form for each species. The last-mentioned is far easier to determine on-site, than by means of literature or herbarium specimens. Where precision is used in determining cover, such as with a point method or the plant number scale, then the addition of mean canopy diameter for each species, permits species

densities to be calculated.

No time-saving advantage was found with computerized field data capture, which also entailed a greater burden in the field.

**Habitat data**

The recommended minimum stand description data to be recorded for each stand are: stand/relevè number; date; and stand centre co-ordinates in degrees, minutes and seconds. In addition, the data required for herbarium labels, such as, major and minor localities and farm name can be included.

It is further recommended that increasing use be made of indirect means of environmental data capture, such as geographic information systems, as these become available, to decrease time spent in the field. Where field observations are made, careful consideration needs to be given to techniques, to ensure adequate samples, because the criteria for floristic sampling is not necessarily the same as that required for environmental sampling.

**Classification**

The aims of a classification are: floristic field data reduction to a comprehensible form, through the grouping of relevès, based on floristic similarity, to form relevè-groups and the grouping of relevè-groups, also based on floristic similarity, so that these can correspond with environmental gradients; and species grouping, based on occurrence in relevès, to emphasize the relationships between relevè-groups.

The classification of a floristic data set can result in more than one solution. A classification should, therefore, be verified to determine classification adequacy.

It is recommended that species-groups, common to two or more relevè-groups, be sequenced to correspond with environmental gradients, where possible. This simplifies the matrix, by reducing the number of species-groups, without loss of species-relationships information and provides more information on gradient relationships.

Care should be exercized in making inferences about vegetation units which are not entirely included in a study area because their total floristic variation is often unknown. This is particularly relevant to small-scale work where large vegetation units are often only partially included in a study area. When synthesizing two or more data sets cognizance should, therefore, be taken of partially included vegetation units.

Justification for splitting data sets to improve species constancy in relevè-groups or improving the classifiability of data sets could not be shown. It is suspected that improvements are obtained by grouping variation within larger units to form separate vegetation units. However, more work is required in this regard.

**Verification**

It is recommended that classification verification include: classification efficiency values; degree of integrity of mapping

units; degree of correspondence between mapping units and stratification; degree of correspondence between classification and differentiating environmental factors; and pattern strength in the constancy of community diagnostic species.

**Derivatives**

The application potential of a classification is directly proportional to the information which can be derived therefrom.

Plant communities are derivatives of a classification and have immense value in land-use practices and planning, at various scales, because of their integrating effect on environmental influences and suitability as mapping units.

Plant community definition, in terms of species constancy in community diagnostic species, in a classified matrix, can be directly proportional to the degree of inter- and intra-community environmental change. However, poor community definition can also be caused by inadequate sampling unit area.

Environmental gradients can be derived directly from classified matrices and more importantly, natural discontinuities in these gradients can be ascertained from vegetation unit borders, within the gradients.

Vegetation structure can be derived from the recommended floristic data making separate structural analyses, as required in the Braun-Blanquet method, redundant.

Community composition analysis is a new approach to analysing community composition, in terms of species cover, frequency, growth forms and structure. The initial results indicate improvements in assessing vegetation condition and suitability for detecting both cover and composition change. However, more analyses are required to confirm these results.

Stand phase analysis combines the components of successional theory with floristically determined data to infer trend and status of stands in relation to the community. As with the community composition analysis, this is a new approach which appears promising but requires more analyses for confirmation.

Community cover assessment for determination of the adequacy of cover within a community, relates to minimum cover for soil conservation. However, these lower limits are based on experience in limited vegetation types and more input is required from other vegetation types before any reliance can be placed on the results.

**PHYTOTAB-PC**

This program package is a comprehensive package, suitable for many aspects of vegetation analysis, with new features, not available in other programs. The package can reduce decision-making, and hence reduce observer bias, with a corresponding increase in objectivity, in vegetation analysis data processing. Time spent on classification can be reduced considerably. The derivative programs have the potential for enhancing the uses to which classifications can be put, thereby increasing the application

potential of the Braun-Blanquet approach. Although the programs are fully documented on-line, and are menu driven, the number of programs and permutations possible, preclude use without an adequate background in Braun-Blanquet methodology and training in program use.

Caution is advised, as has been mentioned, when applying the community cover assessment program as modifications will probably be necessary. Furthermore, the automatic relevè sequencing programs can not be compared with the permutation approach, in all but the smallest data sets, so that the maximum classification efficiency for such larger matrices, can not be known.

Application of the recommended methods can reduce decision-making in vegetation ecology, decrease time spent on certain processes and increase the relevancy of classifications, especially for small-scale work, without conflicting with the basic principles of the Braun-Blanquet method. The derivatives should justify expanded use and application of classifications, especially in agriculture and conservation. In the case of conservation, vegetation should receive the highest priority in South Africa because adequate conservation of vegetation will ensure conservation of other primary natural resources such as soil and soil water.